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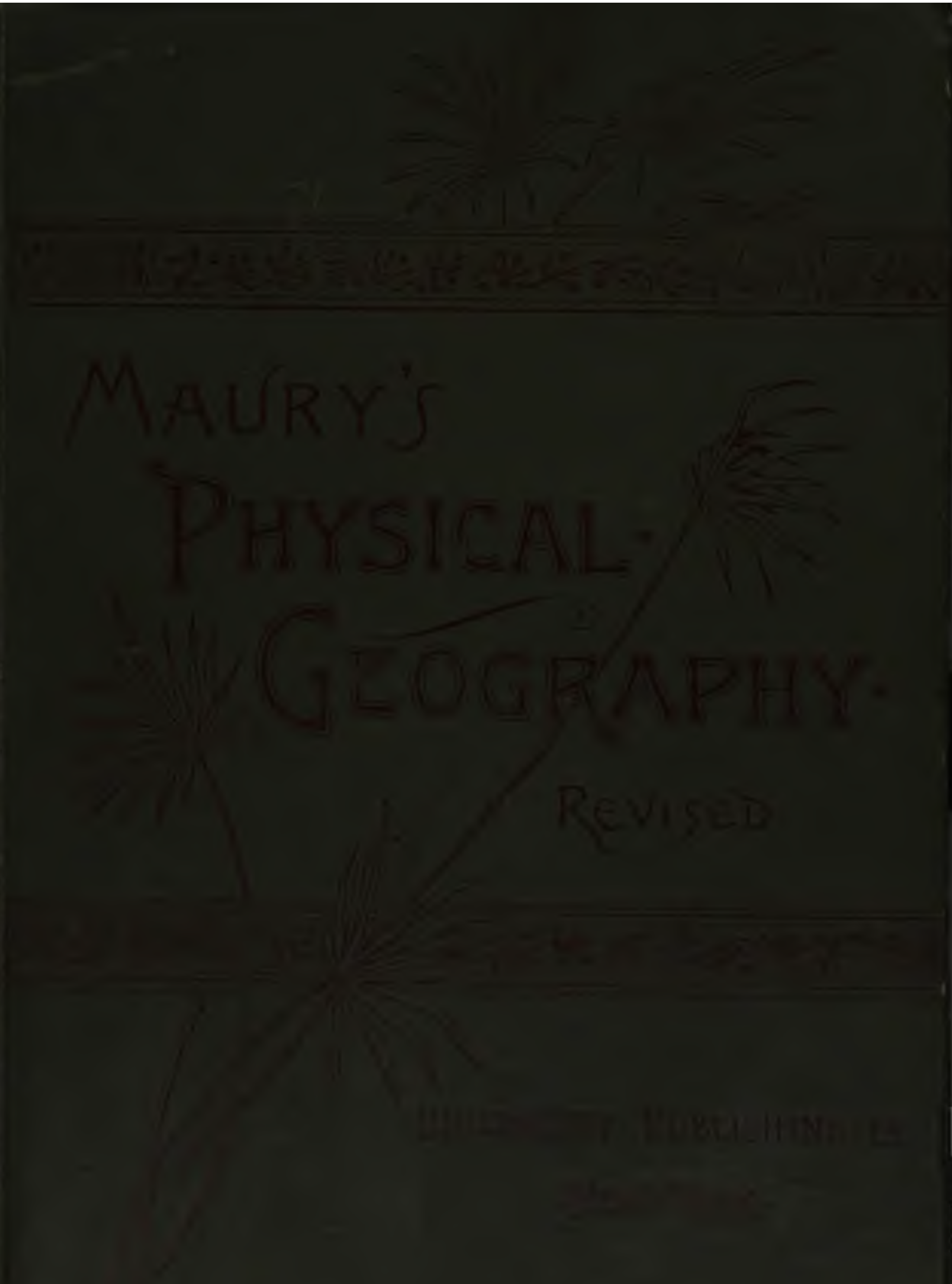

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M. F. MAURY, LL.D.,

AUTHOR OF "PHYSICAL GEOGRAPHY OF THE SEA," LATE SUPERINTENDENT OF THE NAVAL
OBSERVATORY, WASHINGTON, D. C., ETC.

REVISED

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PREFACE.

This volume, together with the three graded Geographies previously published, and a treatise on Astronomy, forming the Author's contribution to the University Series of School Books, was commenced in 1866. It is the joint labor of his wife, daughters, and self, and constituted one of the chief sources of their home recreation during their residence in England. There the best sources of information were kindly and freely opened to him. This, combined with the knowledge and experience acquired or perfected in the superintendency, for fifteen years, of the Washington Observatory, made the undertaking congenial, and the occupation as charming as labors of love always are.

The aim throughout the series has been to strip these two most important branches—Geography and Astronomy—of dry details and mere technicalities, to popularize these fields of knowledge, and make them as interesting and instructive to students as possible.

The Author's investigations for his "Wind and Current Charts," in which he was aided by the vessels and governments of the maritime nations, and the insight that these gave him into the Physical Geography of the Sea and its Meteorology, also afforded him some rare advantages for preparing the present general treatise on Physical Geography.

Besides these special and original sources of information, he has, in the preparation of this work, had access to the best and choicest fountains of recent geographical and scientific knowledge, and has revised his MS. up to the date of going to press.

A science of recent growth, Physical Geography depends for its truths and general principles upon extensive and prolonged observations. These observations have been made for too short a time and over too limited an area, to furnish more than the basis for a complete science. The quickened and enlarged interest that has been awakened in physical researches, the more perfect instruments and appliances that are now used and that will be still further improved, and the patronage and encouragement of enlightened governments, will doubtless lead to the solution of many of its yet unsolved problems.

It has been one of the great aims of the author of this book to prepare its readers and students to understand and take an intelligent interest in this noble science, and especially to awaken in the minds of the young that spirit of observation and patient inquiry which has already won from nature so many of her most hidden secrets.

In the preparation of the numerous charts which enrich the volume, the author has had the assistance of one of the most accomplished chartographers of the country; and the skill and beauty with which they have been engraved upon copper are very gratifying. The pictorial illustrations, which so abundantly explain the text and adorn the pages, have been designed and engraved by some of the first artists in the country, or obtained from European sources, and testify to the liberality of the publishers, and their purpose to present this work to the public in a most attractive garb.

M. F. MAURY.

Lexington, Virginia, November, 1872.

PREFACE TO THE REVISED EDITION.

The progress of science anticipated by the author in the foregoing preface, has rendered desirable the preparation of a revised edition of the Physical Geography. While engaged in this labor, the reviser has sought to meet the demands of our schools for brief books by abridging somewhat the earlier edition, without, however, impairing its completeness. To a considerable extent a re-arrangement of the materials has been adopted. But the aim has been throughout, to preserve, so far as possible, the charm of the author's style.

The typographical arrangement of the text, the topical analysis at the end of each chapter, and the test questions will, it is believed, greatly facilitate the use of the book in the class-room.

In the prosecution of the work the reviser has invoked the counsel of many eminent scientists and experienced educators. To them all he begs to express his obligations for their valuable suggestions. The book owes much to their kind assistance. It is hoped that it will be found abreast of the times, and well adapted to lighten the labor of the teacher, and to kindle the interest of the pupil.

MYTTON MAURY.

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RECENT FACTS

CONCERNING PHYSICAL GEOGRAPHY.

A SUPPLEMENT TO MAURY'S PHYSICAL GEOGRAPHY.

Course of the Gulf Stream.—The theory that a portion of the waters of the Gulf Stream makes the circuit of the Gulf of Mexico has of late been called in question. In this connection the following letter from B. A. Colonna, Assist. Chief Officer in the U. S. Coast and Geodetic Survey Department, is exceedingly interesting and important:

U. S. COAST AND GEODETIC SURVEY OFFICE,
WASHINGTON, *November 24th*, 1887

DEAR SIR:—Your letter of 17th inst. was duly received by Superintendent Thom who referred it to this Office. Press of work on my return from a short leave has prevented earlier attention. I now have the honor to say by direction of the Superintendent that *the exact facts in regard to the circulation of the water in the Gulf of Mexico cannot be stated; we have not had sufficient observations.* The observations of deep sea currents, and the usual soundings were, during the season of 1885–6, confined to the Gulf Stream, on a line from Cape Florida (Fowey Rock Light House) to Great Bahamas; during the season of 1886–7 the work was confined to the vicinity of west end of Cuba, Key West, and Yucatan. None of this work has been published, and none of it would shed any particular light upon the question propounded by you as to the circulation of the waters in the Gulf of Mexico. Our late explorations indicate that the axis of the Gulf Stream hugs the west coast of Cuba closely, and that the Gulf Stream currents are much influenced by the moon in accordance with her time of transit and her declination.

So far as the Gulf of Mexico is concerned I do not think that there is any circular, well-defined current about its circumference. The warm surface water probably flows more freely toward the west coast of Florida than it does toward the coast of Texas or of Mexico. Although this view is founded somewhat on climatic and tidal indications, it is largely inferential. As I have said before, the matter is now under consideration; when we know more about what takes place at the east end of Cuba and thence westward along its north shore to the Strait of Florida, we will be ready to give more particular attention to matters in the Gulf. The great flow of water through the Strait of Florida, northward, must be supplied from somewhere; its surface temperature indicates its recent arrival from the tropics, presumably set into the Caribbean Sea, and up into the Gulf of Mexico, by the trade-winds, and thence propelled in accordance with the laws of fluid motion. Whether the whole supply of water for the Gulf Stream reaches the Florida Strait around the west end of Cuba, or not, cannot now be asserted. It is hoped that the season's work of 1887–8 will shed light upon this subject.

Yours, respectfully,
B. A. COLONNA.

The Velocity of the Gulf Stream.—Recent observations of Lieutenant Pillsbury, of the United States Navy, show that the velocity of the Gulf Stream varies with the position of the moon. "The greatest velocity is about nine hours before the upper transit of the moon. The strongest surface current observed was five and one-fourth knots—the weakest, one and three-fourths—the average three and six-tenths knots." These results are, as a rule, higher than those hitherto given.

It appears also that the speed of the surface water of the Gulf Stream is retarded perceptibly by northerly and north-easterly winds, and accelerated by those from the south-west.

During the coming winter the United States vessel *Blake*, under command of Lientenant Pillsbury, will continue to investigate the Gulf Stream current. She will anchor six hundred miles north-east of Barbadoes, during January and the first part of February, and will be in the track of ships from South Atlantic ports to the United States. The last part of February and until May she will be between the West India Islands, beginning at Trinidad and ending at the cold Bahama Channel. It is expected that Lieutenant Pillsbury's report will be of value, and that some points regarding the Gulf Stream currents will be determined with greater exactness than as yet is possible.

Early Polynesian Navigation.—Mr. Formander has recently made some interesting and instructive discoveries in the folk-lore of the Polynesian islands. He says that "from about the commencement of the eleventh century, for two or three hundred years, the folk-lore in all the principal groups becomes replete with the legends and songs of a number of remarkable men, of bold expeditions, stirring adventures, and voyages undertaken to far-off lands."

For seven or eight generations, the navigators of the leading groups, from the Sandwich Islands in the north to the Society group in the south, and from the Friendly Islands in the west to the Marquesas in the east, were accustomed to interchange visits, and to voyage freely to and fro, with far more assurance and better seamanship than were displayed by the early Greek and Italian sailors in the Mediterranean. Yet the distances thus traversed sometimes exceeded 2,000 miles, and crossed the region of both the north and the south trade winds, and the equatorial calm belt.

Such facts show that, in accounting for the movements of population in primitive times, mere distance and difficulties of navigation need hardly be taken into account. The possible bearing of this upon such questions as the Asiatic origin of the North American Indians will at once be seen.

Sea-level.—Recent observations seem to indicate that along the coast there is no such thing as the popular sea-

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level." The surface of the sea at any given point on a coast will be higher or lower in proportion to the situation and altitude of the neighboring land-masses.

Lofty mountains attract the water and elevate the sea-level above the average height. It is considered, therefore, that the water, being attracted by the enclosing continents, the surfaces of the ocean areas are lower in the centre than at the sides. The depression of the Atlantic centre is estimated by some to be ten or twelve feet; by others far more.

Great Salt Lake is said to have increased about twelve feet in depth during the last twenty years. Its greatest depth is only forty feet. The lake contains no living thing excepting infusoria of poorly defined form, but full of activity. The finest-developed was about three-fourths of an inch in length, and was shaped somewhat like a lobster.

A Cliff of Glass.—One of the wonders of the Yellowstone Park is a cliff of obsidian, which Prof. Joseph P. Iddings, of the U. S. Geological Survey, says "is as true glass as any artificially manufactured." The cliff is about half a mile long by from 150 to 200 feet high, and presents a partial section of a surface flow of obsidian which poured down an ancient slope from the plateau lying east.

Velocity of Advance of Cyclonic Storms.—The average progressive velocity of cyclonic storms is given by Professor Loomis as follows: Bay of Bengal and China Sea, 8.4 miles per hour; West Indies, 13.7; Europe, 16.7; middle latitudes of Atlantic Ocean, 18.0; United States, 28.4. Our lake region seems, therefore, to possess the unhappy pre-eminence of being visited by the fastest-moving, as well as the most numerous storms in the world.

"Lost Rivers."—Numerous "lost rivers" occur in the southwestern portion of the United States. Among the tributaries of the Rio Grande, for instance, there are a number which reach the main stream after a heavy rain, while at other times they are "lost" in a brackish marsh or small lake, or even in the sand of their own bed. One such stream is mentioned which thus disappeared within the space of twenty rods.

The Krakatoa Eruption.—One of the most destructive volcanic eruptions ever known occurred Aug. 27, 1883, in the island of Krakatoa (or Krakatau), in the Straits of Sunda, illustrating what is said in the text (p. 20), on the volcanic activity of this region. The small islands in the vicinity were covered to a depth of from ten to thirty meters with volcanic ashes and pumice, which also fell at sea for hundreds of miles in every direction. Two-thirds of the island were submerged, and the water now covers this area to the depth of 150 to 1,000 feet.

More than 40,000 human beings, overwhelmed by the waves or buried beneath falling cinders, perished on the neighboring islands and the adjacent shores of Java and Sumatra. Krakatoa itself was uninhabited.

Months afterward, vast areas of the ocean, hundreds of miles away, were found nearly covered with floating pumice. Scientific investigation, made under the direction of the Dutch government, indicated that the height of the column of steam and smoke which arose from the crater was from nine to twelve miles, and the amount of solid matter thrown out, over four and a quarter cubic miles. The noise of the explosions was distinctly heard hundreds of miles away.

At Talcahuano, Chili, the ocean rose, on Aug. 28, two feet above high-water mark, indicating that the great wave caused by the earthquake which accompanied the eruption, had traversed the entire breadth of the Pacific.

The Oil Wells of Baku, on the west shore of the Caspian Sea, have reached a yield of a million tons per annum. The earliest wells date back for centuries, but only within the last fifteen years has the work of obtaining the oil been actively prosecuted.

A New Merv Oasis.—General Annenkoff, a Russian engineer, proposes to form, by irrigation, a new oasis 60 to 70 miles in length in southern Turkestan. He suggests diverting a portion of the water of the Oxus into some ancient channels running in the direction of Merv. The soil is clayey, and, if watered, would, it is believed, prove highly fertile. The oasis of Khiva, and another near Merv, were formed in a similar manner.

The Charleston Earthquakes.—For several weeks, dating from August 31st, 1886, a large area of the United States, embracing nearly all the Atlantic Slope and a considerable portion of the Mississippi Valley, has been visited by a series of earthquake shocks.

The starting point of these disturbances was in the Carolinas, and the city of Charleston and its neighborhood were the scene of the most violent and disastrous visitations. Beyond this area, shocks of greater or less intensity were felt as far north as Vermont, and even in the Canadian Province of Ontario; as far south as the Gulf of Mexico; and as far west as Michigan and Missouri. The most violent shock occurred at 9.51 on the night of August 31st.

MAIN FEATURES.—As described by observers, the main features of the disturbance were as follows:

(1.) A *tremor*, violent and destructive near the origin, and diminishing in intensity toward the outer bounds of the area disturbed. An observer at Charleston speaks of it as a "rude, rapid quiver," agitating the lofty strong-walled building in which he was, as though by the hand of some resistless power. "From first to last," he says, "it was a continuous jar, only adding force every instant, until at the point of maximum violence it seemed as though no human handiwork could withstand the shocks. The floors heaved under foot; the walls and partitions visibly swayed to and fro." At Baltimore, a cool-headed observer records how, on the night of the earthquake, he was sitting with one leg thrown over and resting upon the knee of the other, when he noticed his suspended foot swaying at right angles to the direction of his body, with the regularity of a pendulum. At the same time he heard "a sonorous beating of some object" in an adjoining room, keeping time with the oscillations of his foot. Entering this room, he ascertained that the noise arose from the oscillations of his wardrobe, which was backed against the north and south wall of the room. The oscillations had been east and west, and had caused one of the doors of the wardrobe to tap against the partition between the two compartments, so producing the sonorous sounds alluded to. He found by experiment that it required a movement of half an inch at 6¼ feet from the floor to reproduce these sounds with the intensity observed during the earth-movement.

Although it is generally true, as above stated, that the intensity of the tremor diminished toward the outer limits of the area of disturbance, it is of interest to notice that in this, as in the case of other earthquakes, there were, within the area of disturbance, many places where the shock was not felt at all. It is conjectured that such points owe their immunity to geological peculiarities.

(2.) The *sound* which accompanied the tremor was a second element in the phenomenon. This came from below. It resembled the rapid rolling of some heavy body over a floor, or the booming of distant cannon. Like the tremor, it was continuous, and became a "long roar and grinding like ten thousand rusty chariots on a rocky road."

The destructive effects of the earthquake were mainly confined to Charleston and Summerville, South Carolina. Nearly every building of importance in the former place was more or less damaged—many were demolished. Of the churches, scarcely any were left in a condition to be used. The wreck of private houses was terrible. A recent visitor writes under date October 27: "The accounts have not been equal to what I saw. I think every building is more or less damaged. Piles of débris are in every street."

The terror of the unfortunate citizens cannot be conceived. Most of them passed the night of August 31, and several succeeding nights, in the streets and squares. Many persons were injured, and several were killed by the fall of the walls. The records show that this visitation is the ninth which has occurred at Charleston since 1754. It has been the only seriously disastrous one.

Effect upon Domestic Animals.—Among the noteworthy incidents of the Charleston earthquake, were the effects produced upon domestic animals. The engine horses escaped and ran in wild affright, snorting and neighing, to the terror of all they passed. In the country the horses neighed out their distress, and the cows bellowed piteously. Animals that were stabled tried to break away, and failing to do so, trembled and shivered in an agony of fear. Those that were at large fled to the woods and sought to hide themselves from the mysterious danger in thickets and swamps. Half an hour after the frightful shock, a savage looking, but completely scared mastiff, approached a reporter in the city, and licked his shoes, in mute appeal for help.

Cause of the Earthquake.—Little is accurately known as to the causes of earthquakes. An ingenious article appears in *Science*, October 29, 1886, by M. C. Meigs, in which the writer suggests that the phenomena of the Charleston earthquake may be all accounted for on the supposition that vast strata underlying the area of disturbance have been subjected to heat. This would occasion expansion of the part heated—then an outward thrust—then compression, because the expanding portions would encounter resistance from outer masses not affected by the heat—then relief from compression by breakage.

Experimental Illustration.—He considers that a parallel to this series of occurrences may be produced by holding a piece of glass (preferably plate), nearly horizontal, over the flame of an alcohol lamp. The portion heated will expand; compression will result, and in no long time the glass will break with noise and more or less shock. "Here," says the writer, "we have a working model illustrating all the reported phenomena of the Charleston earthquake."

The suggestion is certainly deserving of consideration.

Volcanic Activity.—It is worthy of notice, in connection with the Charleston earthquake, that there has been recently unusual volcanic activity in other parts of the world.

In May, 1886, a grand eruption of Ætna took place.

In July the terrible visitation occurred in New Zealand, which ranks as, perhaps, the most terrific of which we have record; and it is now reported that an eruption occurred on September 31st, on one of the Friendly group, by which seven native villages have been destroyed. And intelligence now reaches us that, on the morning of September 10th, over one hundred heavy shocks of earthquake occurred on the Island of Ninafou, one of the Tonga group, and that from the bottom of the lake, which is 2,000 feet deep, a mountain has arisen to the height of 300 feet above its surface.

Strange Internal Eruption.—Nine miles from Cimmaron, on the Denver and Rio Grande Railroad, in Colorado, the country has been visited by an internal eruption, which has displaced a tract about two miles square. The region was naturally hilly, with a heavy covering of trees. Where there had been hills, valleys now appear, while the valleys have been upheaved into hills. Trees stand in all conceivable positions, some of them being reversed, with their roots free from dirt, the leaves and branches being buried in the debris. The water has disappeared from a large lake, the bed of which is tilted at an angle of 45 degrees. The whole section is so much changed as to make it unknown to those who were heretofore acquainted with it.

Destruction of Wild Animals.—The wild animals of North America, with the exception of a few species of birds, are rapidly diminishing in numbers, owing to their destruction by human enemies. Where, less than twenty years ago, millions of bisons were to be found on the western "plains," there are now but small bands, remotely scattered, of a few dozen each. It is obvious, therefore, that in no long time, certain of our animal tribes will become extinct.

Deep-Sea Fauna.—The expedition of the *Challenger* in the years 1873–76, put us in possession of most important information regarding the animal forms which exist in deep-sea waters. It was conclusively established—

(1.) That the distribution of living beings has no depth limit, but that animals of all the marine invertebrate classes, and, probably, fishes also, exist over the whole of the floor of the ocean.

(2.) It appeared that the enormous pressure, the comparative scantiness of light, and the differences in the chemical and physical conditions of the water do not influence animal life to any great extent, for among the animals captured in the deepest hauls were species nearly allied to those found in shallow water.

(3.) The interesting fact was presented that depths beyond 500 fathoms are inhabited throughout the world by a fauna which exhibits the same general features. In other words, deep-sea genera have usually a cosmopolitan extension, and species are either universally distributed, or if, in remote localities, they differ, there is still a close resemblance among them.

(4.) Some, though not many, types were found existing at abyssal depths which were previously considered to be extinct.

(5.) In its general character, the deep-sea fauna resembles most the fauna of the shallower waters of high northern and southern latitudes; no doubt because the conditions of temperature, on which mainly the distribution of animal life depends, are nearly similar in extreme depths and extreme latitudes.

The above and other conclusions, based upon the results of the *Challenger* expedition, have been, and are being, either confirmed or modified by the researches carried on by the United States Government.

Methods of Work.—The methods adopted now are naturally more systematic, rapid, and effective than those employed twelve years ago on the *Challenger*. The steamer

Albatross has been specially constructed for the work of dredging, and she is manned by a very expert body of naval officers and scientists. Every summer, at least, she cruises in deep ocean waters, and brings back the results to the headquarters of the United States Fish Commission, at Wood's Hole. In the *Challenger* expedition, only one deep-sea dredging could be made in a day, and very little of the bottom was secured at that. On the *Albatross* two to four dredgings per day are made in water over 1,000 fathoms deep, and five in water between 500 and 800 fathoms.

It has been conclusively shown by these later researches that the proportion of animal life in ocean depths is far greater than was indicated by the *Challenger's* results; and, furthermore, that instead of the abyssal forms being comparatively small, many of them are even larger than the analagous forms existing in shallower waters. Among the echinoderms (spine-covered animals, of which our common sea-urchin is a type), taken in depths of 1,346 to 1,735 fathoms, two species are gigantic, one specimen being eighteen inches long.

Results.—Reporting the results of the work done in 1884, Professor Verrill says: "Many additions to the fauna of great depths were made, and a large proportion of them are undescribed forms. Some of the fishes were of great interest. Huge spiny spider-crabs, the outstretched legs of which measured over three feet from tip to tip, were taken in 1,000 to 1,230 fathoms, and another very large crab occurred in great abundance in 500 to 1,000 fathoms. Numerous species of shrimp, many of them bright-colored, and some of very large size, occurred, as usual in the deeper dredgings."

"A striking characteristic of the deep-sea crustacea," says Professor Verrill, "is their red or reddish color. A few species are apparently nearly colorless, but the great majority are some shade of red or orange; and I have seen no evidence of any other bright color. A few species from between 100 to 300 fathoms are conspicuously marked with scarlet or vermilion, but such bright markings are not noticed in any species from below 1,000 fathoms."

Perhaps more remarkable than the matter of coloring is what we learn about the *eyes* of deep-sea forms of life. Of sixteen species taken below 2,000 fathoms by the *Albatross* every one had eyes, and these were distinctly faceted. "In at least three of these species the eyes are not conspicuously different in size from those of allied shallow-water species."

"However strong, therefore, may be the arguments of physicists against the possibility of light penetrating the depths from which these animals come, the color and structure of their eyes, as compared with blind, cave-dwelling species, show conclusively that the darkness beneath 2,000 fathoms of sea-water is very different from that of ordinary caverns."

Red Sunsets and Sunrises.—In the autumns of 1883 and 1884, the sky at sunset, and in a measure also at sunrise, was illuminated with a peculiar rosy light, which diffused itself far up toward the zenith. The phenomenon seems to have been observed all over the world.

Various causes were assigned to account for it. Many scientific men considered that it was due to the presence in our atmosphere of minute volcanic dust emitted during the celebrated eruption of the volcano of Krakatoa, which occurred during the prevalence of the red sunsets. This explanation, however, must be abandoned, for the phenomenon made its appearance, certainly in one region of the world, long before the eruption.

In the "Proceedings of the Manchester Literary and Philosophical Society, Vol. XXIII., Sessions 1883-4," is to be found a letter dated Taranaki, New Zealand, in which the writer says that "for many weeks before that eruption this lurid glow was most strikingly perceptible in New Zealand."

In commenting on this letter, in his report for 1885, Dr. Draper, of the N. Y. Meteorological Observatory, says: "The latest opinion expressed by scientists is that the red sunrises and sunsets were due to the earth passing through meteoric dust in space." And in explanation of the phenomenon being observed first in New Zealand, he says: "May we not conceive that the earth in 1883 was passing through a meteoric cloud, and that the southern hemisphere was the first to enter that cloud?"

Temperature of Deep-sea Waters.—Observations made on the *Albatross*, during 1884, indicated that the temperature at depths of 2,000 to 2,600 fathoms was about 37° Fahr. This temperature, however, was also found at the comparatively shallow depth of 1,000 fathoms. Hence it would seem that, at least in the region of the observations alluded to, the minimum temperature is reached at 1,000 fathoms. The surface temperature taken at the same dates was about 72° Fahr.

It is either owing to the change of temperature experienced in coming from great depths to the surface, or else to the removal of the pressure to which they have been previously subjected, that nearly all the deep-sea animals are dead when brought up in the trawl. Some have enough vitality to make a few feeble motions, but "in all cases they appeared," says Sir W. Thomson, "to have received their death-stroke before they had come out of the water." An exception to this general rule was the case of some coral polyps brought from a depth of 1,000 fathoms. These were alive and expanded when placed in sea-water.

Power of an Ocean Wave.—In a paper by the Rev. Philip Neale, late British chaplain at Batavia, in *Leisure Hour*, speaking of the great inundation from the sea caused by the Krakatoa earthquake, Java, he says: "One of the most remarkable facts concerning the inundation remains to be told. As we walked or scrambled along, we were much surprised to find great masses of white coral lying at the side of our path in every direction. Some of these were of immense size, and had been cast up more than two or three miles from the sea-shore. It was evident, as they were of coral formation, that these immense blocks of solid rock had been torn up from their ocean bed in the midst of the Sunda Straits, borne inland by the gigantic wave, and finally left on the land several miles from the shore. Any one who had not seen the sight would scarcely credit the story.* The feat seems almost an impossible one. How these great masses could have been carried so far into the interior is a mystery, and bears out what I have said in previous papers as to the height of this terrible wave. Many of these rocks were from twenty to thirty tons in weight, and some of the largest must have been very nearly double. Lloyd's agent, who was with me, agreed in thinking that we could not be mistaken if we put down the largest block of coral rock that we passed as weighing not less than fifty tons."

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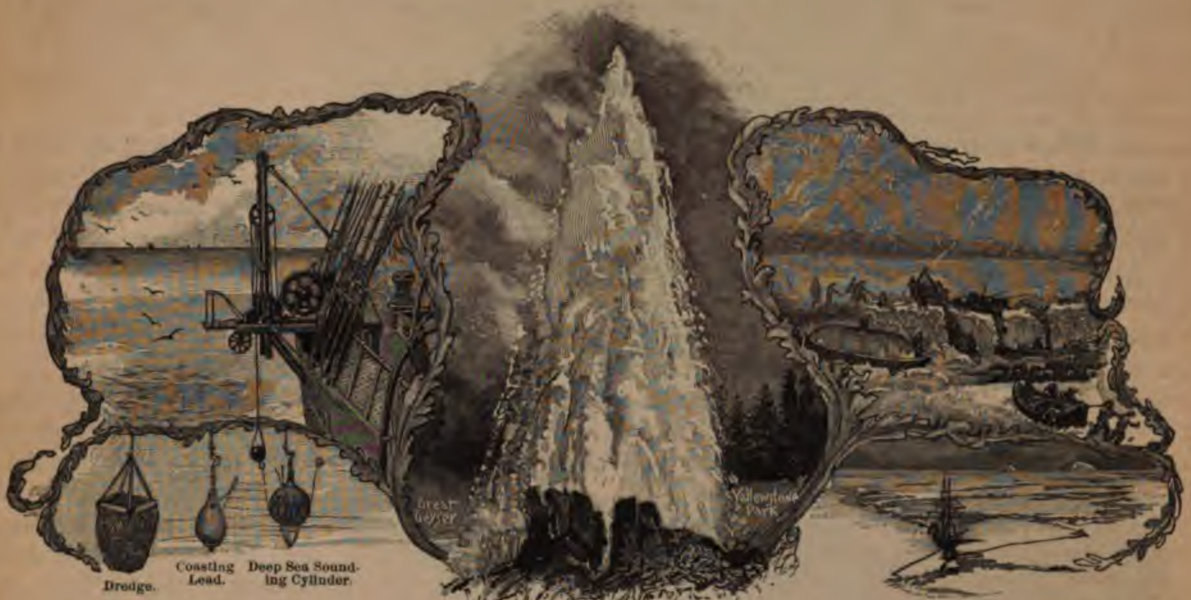
* Compare page 21, paragraph 4, and examples on page 22.

PHYSICAL GEOGRAPHY.



DEEP SEA SOUNDING APPARATUS.*

GREELY ARCTIC EXPEDITION, AUG., 1883.†

INTRODUCTORY.

PHYSICAL GEOGRAPHY invites you to consider the terrestrial machinery which makes day and night, seed-time and harvest; which lifts the vapor from the sea, forms clouds, and waters the earth; which clothes it with verdure and cheers it with warmth, or covers it with snow.

Physical Geography treats of the agents that cause the wonderful circulation of the waters of the sea, that diversify the surface of the earth with hills and valleys, and embellish the landscape with rivers and lakes.

Physical Geography views the surface of the earth, its waters, and its enveloping atmosphere as the scene of the operations of great physical forces, which by their united action render possible the life of plants and animals. It studies the life of the globe whether on its surface or within its waters, taking note particularly of the circumstances which are favorable or adverse to the development of organic forms. It is especially interested in the earth as the abode of man.

Observing in careful detail the various features and agencies of our planet, it considers them as parts of a magnificent machine, by whose operations, under the guidance of the Great Designer, this planet is made a dwelling-place fit for man.

It has been judged most convenient to present the topics treated in the following order:

I. THE EARTH.
II. THE LAND.
III. THE WATER.
IV. THE ATMOSPHERE.
V. LIFE.

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* See Note, page 54.

† Sent out by the U. S. Signal Service Bureau. See Note, page 84.

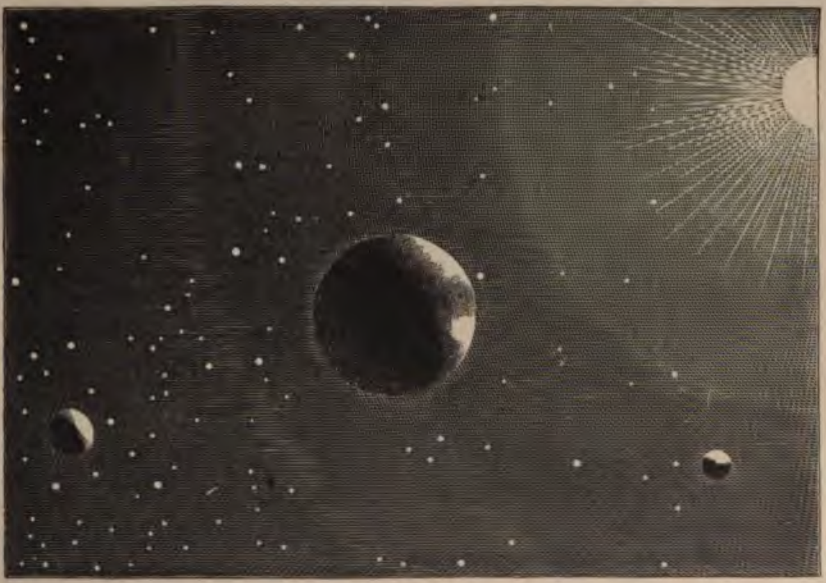
PART I.

THE EARTH.

I. THE EARTH AS A PLANET.

1. What is the Earth?—The first question which requires to be answered in discussing the Physical Geography of the earth is, what is the earth?

ANCIENT THEORY.—Many centuries of human history passed before any one was able to answer this question correctly. Men saw the sun in the same part of the heavens morning after morning, and when his light faded, they observed that the stars were apparently just where they had been the night before. It was concluded that the sun and stars all moved round the earth once in twenty-four hours.



EARTH AND MOON IN SPACE.

Thus the early answer to our question was that the earth was the centre of the Universe.

Careful observation seemed to confirm this idea. Astronomers watched the heavens. They mapped down the stars, and recorded from night to night the places of the brightest among them. They observed that some of them did not change their position with reference to their companions, while others very perceptibly varied theirs. The former were called *fixed stars.* The latter received the name *planets,* or wanderers, from a Greek word meaning to wander. What did their wandering mean? It was found that after certain periods each of the planets returned to its old place in the heavens. This was deemed conclusive proof that the planets, together with the sun and moon, revolved in circles round the earth. This explanation was satisfactory to the majority of mankind, but not to thoughtful astronomers.

THEORY OF COPERNICUS.—In 1542, Copernicus, a Prussian astronomer, startled the world by announcing that the ancient theory was a mistake; that the sun, not the earth, is the centre of the Universe; that the planets, instead of circling round the earth, revolve round the sun; and that *the earth itself is only a planet.*

Thus the true answer to our question, learnt only about three hundred years ago, is that the earth is not utterly unlike the heavenly bodies, as it seems to us to be; but that it is actually one of them, and that, if we were placed upon one of the other planets, the earth would appear as a shining star-like point in the sky.

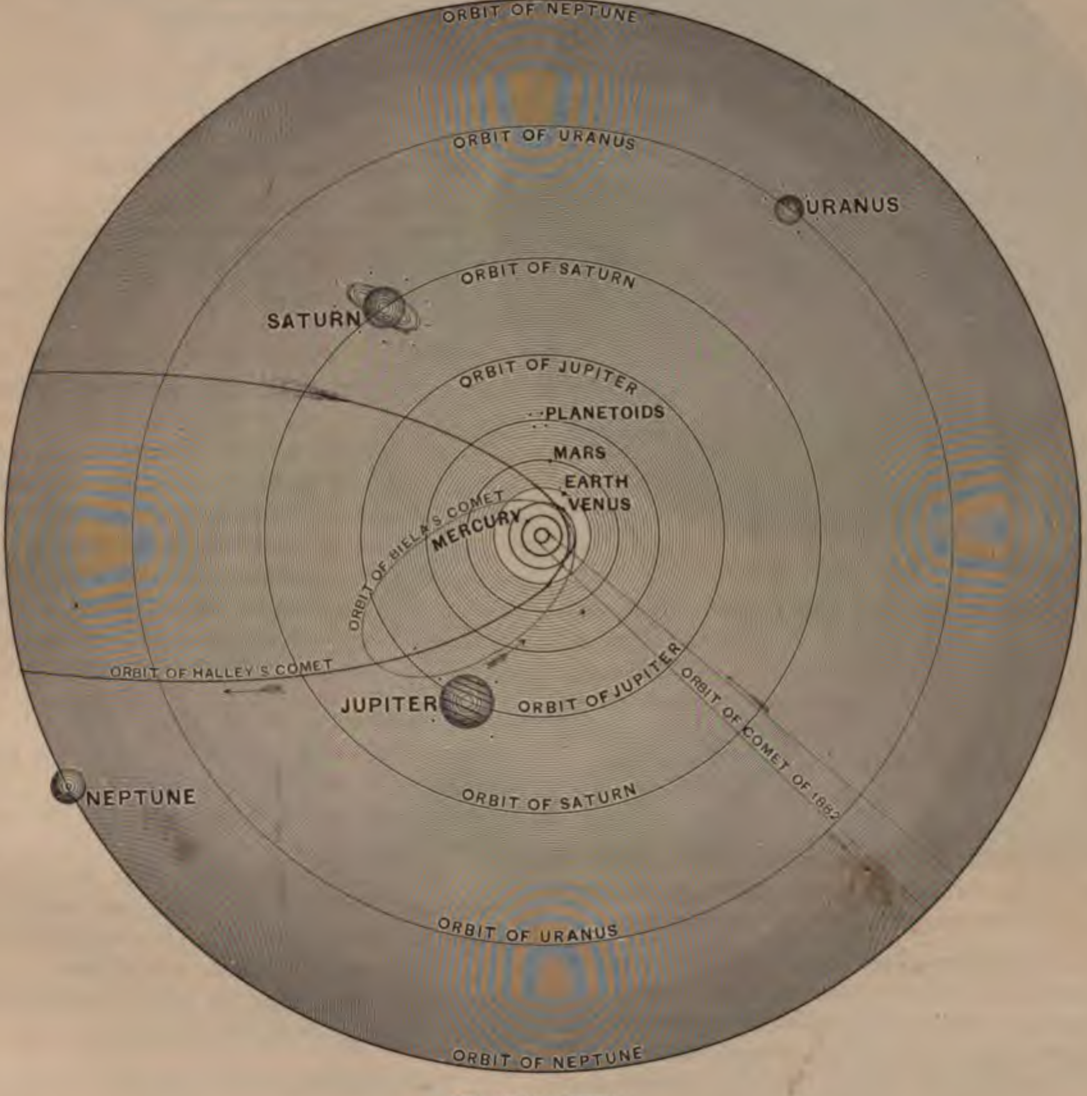
2. The Solar System.—The Sun and its attendant planets with their satellites, together with the planetoids and comets, constitute what is known as the Solar System, so called from the Latin *sol,* the sun.

A "system" consists of one central body, together with other smaller ones which move round it.

THE SUN.—The sun is the centre of the Solar System. From it all the planets derive both heat and light.

The sun is a vast sphere or ball, more than a million times as large as the earth. If we could place its centre where the centre of the earth is, then the sun would reach so far into space that it would extend almost 200,000 miles beyond the orbit of the moon.

The sun is shown by the spectroscope to contain many of the same materials as those of which the earth is composed. It is in a state of intense heat, and columns of incandescent gases project from its surface tens of thousands of miles into space.



THE SOLAR SYSTEM.

The heat received in one year by the earth from the sun, would, if distributed uniformly, melt a layer of ice 100 feet thick covering the entire globe.

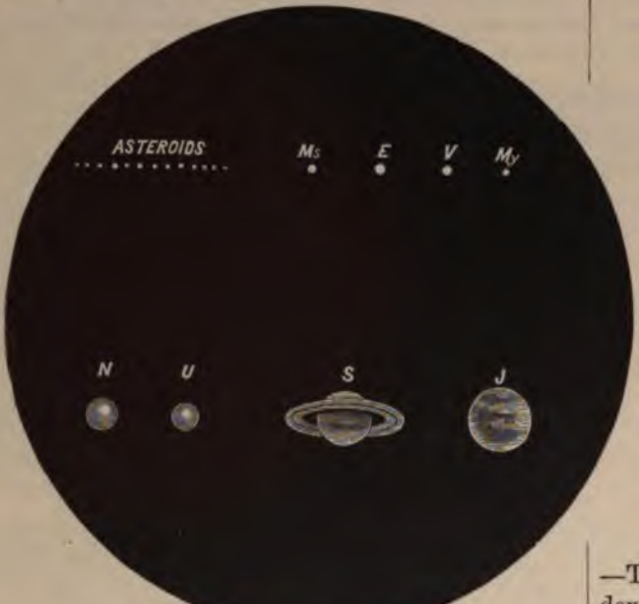
THE PLANETS.—The planets are classed as Primary and Secondary.

The *Primary Planets* are eight in number. They are Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus and Neptune. These names are given in the order of their distance from the sun, Mercury being the nearest. Between Mars and Jupiter are the Planetoids, or Asteroids, more than 200 in number. They are so small as to be, for the most part, invisible to the naked eye.

The *Secondary Planets* revolve round the Primary Planets, as the Primaries revolve round the sun. They are also called moons and satellites. Our moon is the satellite of the Earth.

The Nebular Theory is now held by all astronomers. It supposes that all the bodies constituting the Solar System were originally one mass of matter in a nebulous or cloud-like condition. This was widely diffused through a certain portion of space, and had a rotary motion. From causes unknown to us, parts of it successively condensed and became semi-solid. Being detached or thrown off from the general mass, these formed the various members of the Solar System, the most distant from the centre being the earliest formed. The sun is considered to be a portion of the nebulous matter which is in an incandescent state, owing perhaps to chemical and physical changes going on among its elements.

If the earth be represented by a globe one foot in diameter, the sun must be represented by a sphere 35 yards in diameter, and be 2¼ miles from the globe, so as to show in proper proportion the real size of the two bodies and the distance between them. Jupiter, the largest planet, would be represented by a globe 3½ yards in diameter at the distance of 11 miles. The relative sizes of the disks of the sun and planets are approximately represented below.



RELATIVE SIZE OF THE SUN AND PLANETS.

3. *Actual Size of the Earth.*—The equatorial diameter of the earth is 7,925.65 miles; the polar, 7,899.17. The difference is about 26½ miles. The region about each pole, therefore, must be compressed 13¼ miles. The circumference of the earth at the equator is 24,899 miles. Its volume, or solid contents, is about 260,000,000,000 cubic miles.

The specific gravity of the earth is about 5½, that is, the earth is five and a half times as heavy as a globe of water of equal dimensions would be.

4. *Comparative Insignificance of the Earth.*—If now we bear in mind that all *the fixed stars are the suns of other systems* resembling our own, and in many cases vastly larger * than our own, and reflect that the heavens above and below us are filled with untold numbers of such systems, we shall appreciate the comparative insignificance of our earth.

The earth is only one of the smallest members of one of the numberless systems which fill the immensity of space.

TOPICAL ANALYSIS.

I. THE EARTH AS A PLANET.

1. What is the Earth?

Ancient Theory. Fixed Stars. Planets. Theory of Copernicus.

2. The Solar System.

Classes of bodies included in it. The Sun. Relation to Solar System. Size. Materials composing it. Its heat. Planets. Primary Planets. Planetoids. Secondary Planets. Nebular Theory. Relative sizes of Sun and Planets.

3. Actual size of the Earth.

Diameter. Circumference. Volume. Specific gravity.

4. Comparative insignificance of the Earth.

TEST QUESTIONS.—[The test questions are to be used at the option of the teacher. They are not directly answered in the text. Their design is to awaken thought on the part of the pupil.] Name all the bodies you can that may be seen in the heavens. What would be the consequence to the earth, if the heat of the sun should be withdrawn?

II. PLANETARY MOVEMENTS.

1. *Effects of the Earth's Motions.*—The nature of man requires for its highest development that he shall have certain alternations in the degrees of light and heat to which he is subjected. The planetary motions of the Earth produce just the changes which he needs. They are those of day and night, and summer and winter. Let us see how these are brought about.

2. *Rotation.*—All of the planets rotate on their axes from west to east.* This motion causes alternations of sunshine and darkness.

The nearer a planet is to the sun, the less rapidly it rotates. Mercury, Venus, and the Earth rotate in about twenty-four hours. The more distant planets, so far as their rates have been ascertained, require only about nine or ten hours for their rotation. Their day is less than half of ours.

It is easy to see that its brevity would be very inconvenient to beings like ourselves.

3. *Revolution.*—The planets, while rotating, also revolve round the sun.

The direction of this planetary revolution is, like that of rotation, from west to east, and, with the exception of the satellites of Uranus, and possibly those of Neptune, all the secondary planets revolve in the same direction. The *time* required for a single revolution is called a year.

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* The subordinate position of the Solar System in the universe is strongly suggested by the fact, that the entire system appears to be moving through space in the direction of the constellation Hercules. Motion towards indicates an attracting force; and implies that the body exerting that force is larger than the body which is attracted. How vastly grander than our system must that one be which can draw toward itself our sun with its inconceivable volume, and the attendant planets!

* An interesting evidence of the earth's rotation is that suggested by Newton. It is easy to see that a body at the top of a tower will, if the earth really rotates, move with greater velocity than will the base of the tower. Let a ball be dropped from the top of such a tower, and it will strike a point on the ground some distance from the foundation. Experiments of this kind have all clearly demonstrated the easterly motion of the earth, the balls dropped always striking

The nearer a planet is to the sun, the more rapidly it revolves, and the shorter is its year. The year of Mercury, the nearest planet, is only eighty-eight days long: Jupiter's year consists of about eleven of ours: Neptune's of more than 160. The earth completes its revolution in 365¼ days.

4. Inclination of Planetary Axes.—The axes of the planets are inclined to the planes of their orbits. The angle or amount of inclination is not the same for all the planets. Each has its own. But it is important to observe that the angle of inclination of each planet undergoes no change. It is said to be "constant." And again the axis of each planet preserves invariably the same direction at every point of the orbit; in other words, at any two points of the orbit the axis is parallel to itself.

The facts that the planetary axes are inclined at constant angles, and preserve unchanging directions, bring about, in combination with the revolution of the planets, two results: (1) changes of seasons; (2) variations in the duration of day and night.

SEASONS.—An inspection of the cut opposite will show that as each planet passes round the sun, the upper portion of its surface will be directed toward the sun at one part of its orbit, the lower at the opposite part. In other words, the northern hemisphere of each planet will receive the more direct rays of the sun at one time, the southern at another. A hot season, or summer, will therefore alternate with a cold season or winter.

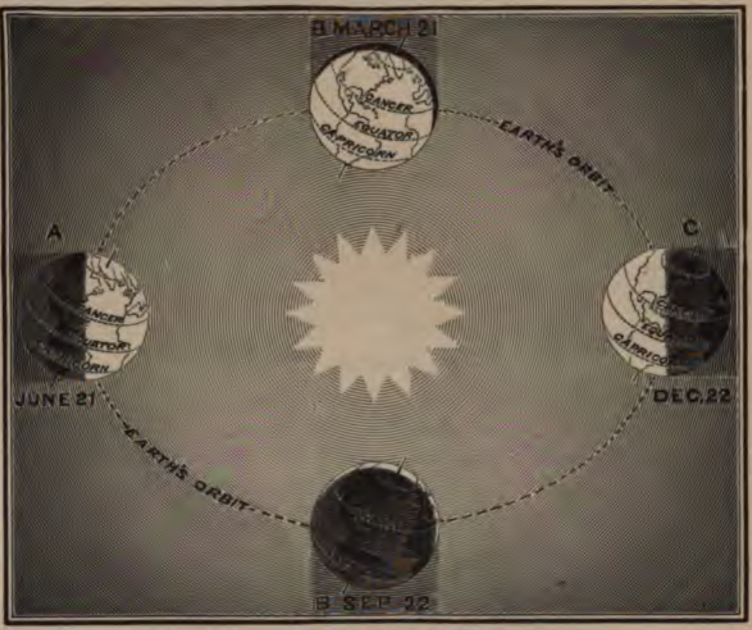
The Earth's Axis is inclined to the plane of its orbit at the constant angle of about 23½°. This inclination, combined with the earth's orbital motion, makes *our seasons.*

The sun appears every year to move through the heavens northward as far as the Tropic of Cancer, and southward as far as the Tropic of Capricorn. In the course of this journey he is directly over our equator, or, to use the sailor's phrase, "crosses the line," on or about the 21st of March. Just as soon as he passes northward of the equator, his light leaves the south pole, and extends to and beyond the north. The winter of the south polar regions now begins, and that of the north polar regions ends. Still travelling northward the sun carries the hot season with him, and summer ls throughout the northern hemisphere.

verse of all this occurs while the sun journeys

VARYING LENGTH OF DAY AND NIGHT.—A second effect of this inclination of the axes of the planets to their orbits is that their periods of light and darkness, or day and night, vary in length according to the apparent position of the sun at the different seasons.

In the case of the earth, twice every year, in March and in September, when the sun crosses the equator, the equinox occurs; that is, daylight and darkness are of equal duration all over the globe. Each is twelve hours long. This is because the light of the sun, when he is on the equator, extends from pole to pole, and one half of every parallel is in sunlight and the other half in shade. But, as the sun moves northward, the duration of daylight is greater and greater for all places north of the equator, until about the 21st of June, when the summer solstice occurs. Then the north pole of the earth is turned toward the sun and the northern hemisphere has its longest day.



ORBIT OF THE EARTH.

The summer solstice being past, the sun begins to recede toward the south. Our days then become shorter and shorter, until, toward the end of December, we have our shortest day. The sunshine then lasts for us only about nine hours. The winter solstice being past, the days again begin to lengthen. [For the effect of this upon the climate of northern latitudes see paragraph 2 on page 70.]

5. Adaptation of the Earth for Human Habitation.—Comparing the earth with the other planets, we observe two points which render it specially adapted for human habitation: (1) its position with reference to the sun; (2) the moderate inclination of its axis.

Owing to its distance from the sun, and the consequent moderate intensity of its heat and cold, as well as the medium length of its year, the earth occupies a most favored situation in the Solar System. We are not so near to the sun as to be, like Mercury, exposed to destructive heat; nor are we so remote as to encounter unendurable cold. The nearer planets must be too hot; the more distant quite too cold for human habitation.

Again; the length of our year and the duration of its seasons are admirably suited to human needs. Supposing Mercury, Jupiter and Neptune to have four seasons as we have, it is obvious that they would be entirely unsuited to be the residence of beings like ourselves. The seasons of Mercury would be about three of our weeks in length; those of Jupiter, three of our years; while on the planet Neptune a single season would be forty earthly years in duration.

Owing, moreover, to the moderate inclination of its axis, the earth has polar regions of restricted extent. The vast proportion of its surface is habitable for man.

It is obvious [see cut, p. 9] that what we call the polar regions of each planet are of greater or less extent in proportion to the amount of inclination of the planetary axis.

The inclination of the axis of Venus is believed to be 75°. Consequently its polar regions will extend 75° from either pole. Nearly the whole surface of the planet, therefore, must have only two seasons; one of intense heat, the other of equally intense cold.

TOPICAL ANALYSIS.

II. PLANETARY MOVEMENTS.

1. **Effects of the Earth's Motions.**
   Influence upon the needs of man.
2. **Rotation of Planets.**
   Direction. Relation of velocity of rotation to distance from sun.
3. **Revolution.**
   Direction of the motion. Relation of velocity of revolution to distance from sun. Illustrations.
4. **Inclination of Planetary Axes.**
   Unchanging amount and direction of the inclination. Results in change of seasons. In varying length of day and night. Equinoxes and solstices.
5. **Adaptation of the Earth for human habitation.**
   Two causes of this adaptation. Seasons of the other planets.

TEST QUESTIONS.—If the inclination of the earth's axis were increased, how would that affect our seasons? How, if the inclination were diminished? Where are the sun's rays vertical when we have our longest day? Where are they vertical when the days and nights are equal?

III. MAGNETISM OF THE EARTH.

1. How demonstrated.—Among the properties which belong to the earth as a whole, is its Magnetism. An understanding of this subject is best reached by noticing the phenomena of those bodies which we call *Magnets*, and then comparing with these phenomena, certain ones which are exhibited by the earth. The result will demonstrate that the earth is a magnet.

2. Magnets.—Magnets are either natural or artificial. The properties exhibited by both are identical.

NATURAL MAGNETS are pieces of a kind of iron ore commonly called the *loadstone*. This ore was first found near a city of Asia Minor called Magnesia; and hence the magnet received its name.

ARTIFICIAL MAGNETS are readily made by rubbing a piece of tempered steel upon a natural magnet, or upon a bar of steel already magnetized, or by the employment of currents of electricity. According to their shape and size artificial magnets are called *bar magnets, horseshoe magnets,* or *magnetic needles.* The last are such as are employed in compasses.

3. The Properties of the Magnet are among the most extraordinary of material phenomena. They are closely akin to those of electricity.

MAGNETS ATTRACT pieces of iron and steel. They also attract other magnets. This action will occur, even though the magnet and the body attracted are at a considerable distance from each other, or even if some substance, like glass, intervene between the two.

MAGNETS HAVE POLES.—If a magnet be suspended so as to be free to move, one end of it points invariably to the north, the other to the south. The two ends are, therefore, called the north pole and south pole of the magnet.

If now we bring two magnets near one another, a very singular effect is produced. The north pole of the one is attracted toward the south pole of the other; the south pole of the one is drawn toward the north pole of the other. But if the north pole of the one be presented to the north pole of the other, they repel one another. The north pole of the one that is free to move swings away. In like manner, if the two south poles be placed near one another, they mutually repel.

Thus we see: (1) *that the magnetic forces at the opposite poles are opposite in certain respects; and* (2) *that like poles repel, unlike attract.*

NEUTRAL LINE.—About half-way between the north and south poles there is a *neutral line,* extending across the magnet. Along this line the opposite magnetic forces neutralize each other.

If a piece of iron, or a magnetic needle, be suspended exactly over this line, it will not be attracted at all. On either side of it, however, a suspended needle is drawn toward one or the other of the poles. The *exact* position of the neutral line depends on the relative strength of the poles. As these are seldom if ever of equal strength, the neutral line will rarely or never be equidistant from both.

4. The Earth a Magnet.—In some very important respects the earth behaves like a magnet.

ATTRACTIVE POWER.—In the first place it displays attractive power precisely similar to that of the magnet. It is terrestrial magnetism which causes magnets to point northward when suspended.

MAGNETIC POLES.—Secondly, like the magnet the earth has magnetic poles. These are not exactly at the north and south geographical poles, but at some distance from them. They are the points at which the needle stands vertical. The north magnetic pole is in North America. It is situated in Boothia, latitude 70° north, longitude 97° west. The discovery of this pole was made by Sir James Ross in 1830.

The position of the south magnetic pole has not been so accurately determined. Sir James Ross reached a point in the Antarctic Ocean where the inclination was 88° 37′, from which its situation has been computed. It is not, however, diametrically opposite the north magnetic pole, but far to one side. It lies in the vicinity of lat. 75° S., long. 134° E. The position of both these poles is constantly changing.

NEUTRAL LINE.—Thirdly, the earth, like a magnet, has a neutral line. This line encircles the globe about midway between the north and south magnetic poles. Along it the opposite polar forces counteract each other. It is called the *magnetic equator*. Its course is traced upon the chart.

5. Inclination or Dip of the Needle.—As you go northward from the magnetic equator, the north end of the needle is drawn downward from a horizontal position until you reach the magnetic pole, and there the needle, as already said, points vertically. As you go southward from the magnetic equator, the south pole, in like manner, is drawn down, until at the south magnetic pole the needle would again become vertical.

The amount of deviation from the horizontal position is called the *Inclination* or *Dip* of the needle. Only upon the magnetic equator or neutral line is there no dip.

6. Declination of the Needle.—While magnets free to move assume a north and south direction, they do not point exactly to the true geographical north, but a little to the west or the east of it. The deviation from the true northerly position is called the *declination* of the needle.

Declination differs in different places, both in direction and amount.

The direction in some places is east, in others west. It will be seen from the map that over about one half of the globe it is easterly, over the other half, westerly. The amount of declination is greater in some places than others. In Liverpool, Edinburgh and Glasgow, it is about two degrees greater than at London.

VARIATIONS.—The intensity and position of the forces which cause the needle to deviate from the true north and south direction are constantly changing. Hence there arise, (1) secular variations; (2) diurnal variations.

Secular Variations extend over long periods. The declination at London was east in 1580, and amounted to 11° 36′; in 1663 it was zero; in 1818 it attained its maximum, 24° 41′, and was west. In 1877 it had decreased to 19° 3′ west. It is therefore decreasing at the rate of about 5′ annually; so that in 200 years it will probably be east again.

In *diurnal variations* the needle moves from east to west, from 8 A.M. till noon, and back again in the afternoon. In Washington City the variation is about 14′.

LINE OF NO VARIATION.*—Just as there is a magnetic equator along which there is no dip or horizontal deviation, so there are lines on which there is no declination. Such lines are commonly known as "*lines of no variation.*" †

There are two such lines, one in the eastern hemisphere, and one in the western. Their position is constantly changing. In the time of Columbus the western line was about 20° west of the Azores. It now passes through the West Indies.

7. Magnetic Storms.—Unusual and violent fluctuations of the needle indicate the prevalence of magnetic storms. Such storms take place during displays of lightning, but more particularly during the occurrence of the Aurora Borealis. One of the most violent on record occurred November 17th, 1882. It prevailed throughout the United States, and even extended to Europe. Chicago seems to have been the focus of the disturbance. Here "operating keys" were in some cases melted. Telegraphic communication was practically suspended throughout the country, and even the ocean telegraphs were disabled for many hours.

8. Sun-Spots and Terrestrial Magnetism.—It is believed that there is a relation between the spots observed upon the sun and the magnetism of the earth.

The sun-spots are periodical, both as to number and frequency. They attain their maxima and minima in from ten to twelve years. The magnetism of the earth seems to follow the same law of variation. Auroras and magnetic disturbances appear to be most frequent when the sun-spots are most numerous. Hence it is argued that some intimate relation probably exists between these phenomena.

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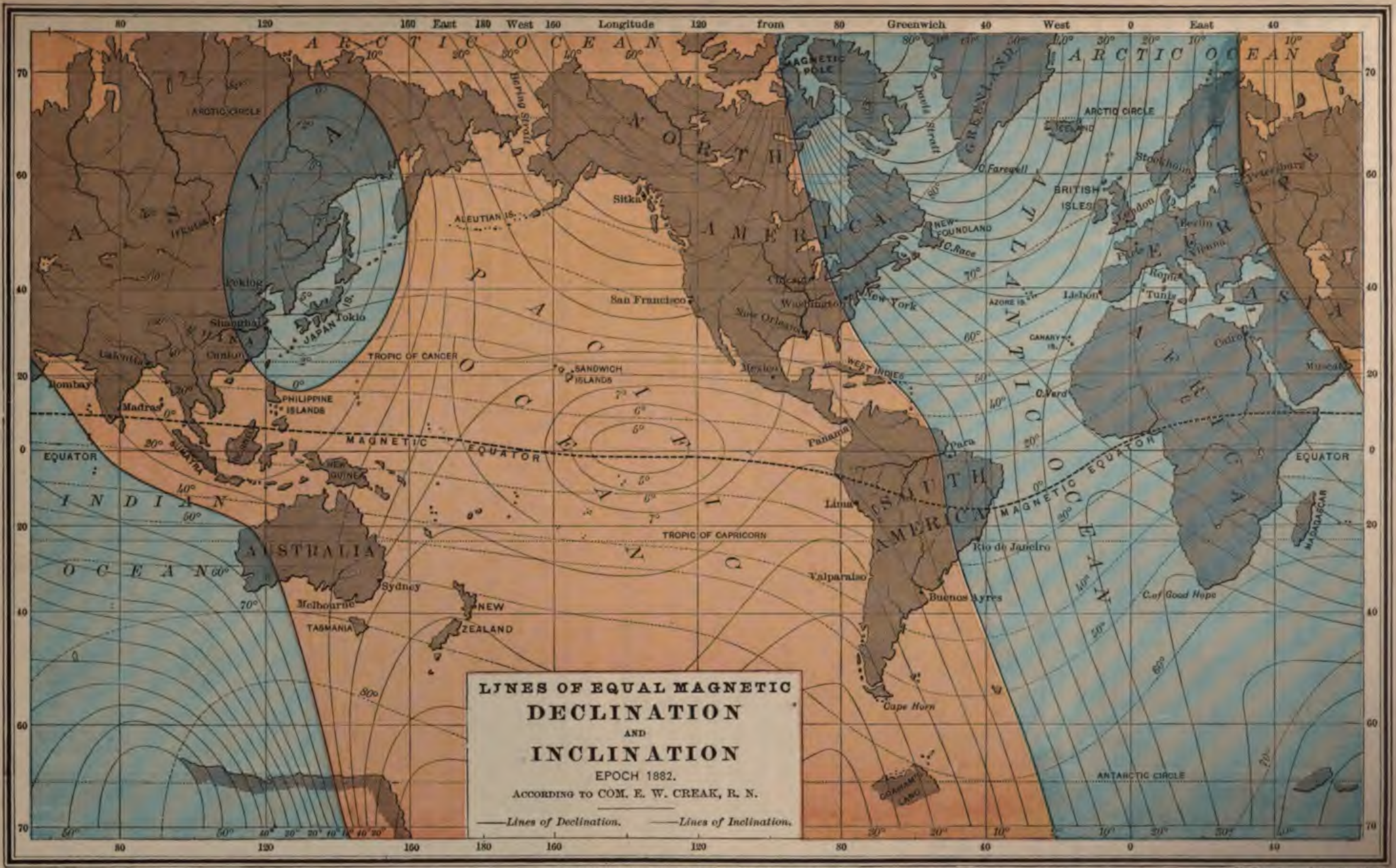
* The interest attaching to this line is great. Spain and Portugal quarreled about the possession of the lands discovered by their navigators in the 15th century. The pope directed that the "line of no variation" should be the boundary between them. All lands discovered to the eastward of this line were to belong to Portugal, all to the westward to Spain. Spain was determined to possess herself of some of the East India Spice islands, but she could claim them only by making it appear that they were to the westward of the 20th meridian. Hence Magellan proposed, in the interest of the King of Spain, to reach the Moluccas by sailing westward. His voyage resulted in the circumnavigation of the globe.

† Variation here means declination.



LINES OF EQUAL MAGNETIC DECLINATION AND INCLINATION

EPOCH 1882.

ACCORDING TO COM. E. W. CREAK, R. N.

——Lines of Declination. ——Lines of Inclination.

Engraved for Maury's Physical Geography.

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Struthers, Servoss & Co., Engr's N.Y.

Note upon the Map.—The buff color indicates easterly declination, the blue westerly. The lines which diverge from the magnetic poles have numbers affixed to them which show the amount of declination. A curious oval is observed upon the buff space. It embraces part of China and the Japanese Islands. Within its limits the declination is abnormal. It is westerly. From this it is inferred that there probably exists another, though subordinate, north magnetic pole in Northern Asia.

9. Causes of Terrestrial Magnetism.—If a current of electricity is made to pass round a piece of soft iron, the latter acquires magnetic properties, and retains them so long as the current lasts. If vast currents of electricity passed round and round the earth, they would convert it into a gigantic magnet. This, it is believed, actually occurs.

The sun's rays, resting successively on different portions of the earth's surface as it rotates, produce thermo-electric currents ; *i.e.* electric currents produced by heat. These follow the apparent course of the sunlight from east to west round the globe, and convert the earth into a magnet.

The above-noted relation between magnetism and sun-spots seems to corroborate this theory.

10. Uses of Terrestrial Magnetism.—It might seem that the magnetism of the earth is only a curious and interesting fact. But its bearing upon the welfare of the human family is marvellous. To it we owe the compass, and to the compass the possibility of modern navigation. Without his magnetic needle ever pointing northward, how could the mariner find a pathway over the trackless waters, and steer unerringly for "the haven where he would be ?"

TOPICAL ANALYSIS.

III. MAGNETISM OF THE EARTH.

1. **How demonstrated.**
2. **Magnets.**
    Natural. Origin of name. Artificial. Modes of making. Kinds.
3. **Properties of the Magnet.**
    Attraction. Magnetic Poles. Law of magnetic attraction. Neutral line.
4. **The Earth a Magnet.**
    Attractive power. Magnetic Poles. Neutral line.
5. **Inclination or Dip of the Needle.**
    Effect upon the needle of approaching the magnetic pole.
6. **Declination of the Needle.**
    Definition. Variations in declination. Secular. Diurnal. Line of no variation.
7. **Magnetic Storms.**
    Indications. Times of occurrence.
8. **Sun-spots and Terrestrial Magnetism.**
    Supposed relation between.
9. **Cause of Terrestrial Magnetism.**
    Influence of electric currents.
10. **Uses of Terrestrial Magnetism.**

Note.—In connection with this subject the teacher might advert to the disturbing effects of iron vessels upon compasses ; the loss of vessels from this cause, and the means adopted to counteract the attraction of the iron used in the construction of vessels.

IV. INTERNAL HEAT OF THE EARTH.

1. Evidences of Internal Heat.—While the crust of the earth is generally of a moderate temperature, there are various reasons for believing that its interior is in a state of intense heat. Three sources of proof may be mentioned : (1) mines ; (2) hot springs, geysers, and artesian wells ; (3) volcanoes.

Mines.—As we descend through mines into the interior of the earth, we find the temperature to increase at the rate of about 1° Fahrenheit for every 50 feet of perpendicular descent. In very deep mines it is impossible for miners to exist without a constant current of fresh air to reduce the temperature. A limit is soon reached, beyond which, owing to the increase of heat, mining is impracticable.

The greatest depths at which miners have found it possible to work are about 2,500 feet below the surface.

In the Consolidated Virginia and California Mine in Virginia City, which has a depth of 2,000 feet, the temperature is 115° Fahrenheit. The miners are divided into gangs, each gang working twenty minutes and resting forty. They drink ice water freely, and apply ice to their wrists to cool the circulation.

At Monderf, in Luxemburg, a mine has been sunk to the depth of 2,920 feet, and one at New Salzwerk, in Prussia, is 2,280 feet deep.

Artesian Wells bear testimony to the same rapid increase of heat. These have been sunk in various parts of Europe and America to a depth varying from 1,000 to 4,000 feet.

The rate of increase in the temperature varies in different places. The average is 1° Fahr. for 50 to 70 feet. The temperature of the well at Grenelle, near Paris, is 81.7° Fahrenheit. Its depth is 1,798 feet. That at Buda-Pesth is 3,160 feet deep. Its temperature is 178° Fahrenheit. It supplies a large part of the city with warm water.

Experience shows that by boring artesian wells, jets of warm water may be obtained in almost every region of the earth.

Hot Springs are found in countless numbers in various parts of the world. They are most abundant in volcanic regions; but they are not confined to the vicinity of volcanoes. Those of Bath, in England, are more than 1,000 miles from either Etna or Vesuvius. More than 1,500 exist in Europe. The cut below shows those of St. Michael, one of the Azores.

BOILING SPRINGS OF ST. MICHAEL (AZORES).

The temperature of these springs seems to indicate that everywhere, not far below the surface of the ground, some source of high heat exists. The Arkansas hot springs vary from 110° to 150° Fahrenheit. One of those in Iceland is 49° above the boiling point.

Geysers are intermittent hot springs. The temperature of their waters rapidly rises with every few feet of descent. The surface water of the Great Geyser of Iceland Bunsen found to have an average temperature of about 180°. At the depth of 72 feet the temperature was upwards of 250°. This high temperature is probably due to the same causes as produce the heat of volcanoes.

Geysers occur in volcanic regions, and within limited areas. The most noted are those of Iceland, the Yellowstone Park, where there are said to be several thousand, and New Zealand.

The region where they are chiefly found in Iceland is about two miles square. Within this space are nearly one hundred openings or geyser mouths piercing the ground.

Description.—The mouths of geysers are surrounded with rims of variously colored incrustations. These rims vary in size from a few inches to many feet in diameter. That of the Great Geyser is fifteen feet in height, and fifty-six feet in diameter. In the centre of this monstrous basin is a pipe or funnel eight feet wide. Out of this funnel boiling water constantly issues. Eruptive discharges also occur. There are certain premonitions when these are about to take place. At intervals of a few hours underground rumblings are heard: the water in the basin boils furiously, and jets of hot water with clouds of steam are thrown up to the height of several feet.

Several of these intermittent discharges occur, and then succeeds a grand eruption. With a rumbling that shakes the ground, a huge column of boiling water 150 or 200 feet high is forced up into the air with loud explosions and amid clouds of steam. The basin and pipe are thus emptied of water. But at once they begin to fill up, only to be emptied again by another grand explosion.

Of the Yellowstone Geysers an observer says:

Of all the geysers whose eruptions we witnessed, the Grand was, I think, the most interesting. It played each evening at a regular hour. Suddenly, with a single prefatory spurt, it shot a vast stream of water over two hundred feet into the air. This was maintained for a few minutes with unabated vigor; then it suddenly ceased, and the waters shrank back out of sight into the cavernous hollow below. Meanwhile subterranean thunder shook the ground. After a minute's cessation, the geyser again burst forth with even greater violence. This continued until nine successive pulsations had occurred.

Volcanoes are the most striking of all manifestations of the earth's internal heat. They are so important that they will be considered in detail in a subsequent lesson. Here, however, it is proper to observe what strong confirmation they afford to the theory of central heat. Streams of lava, white-hot, like molten iron, issue through their craters from the interior of the earth.

2. Condition of the Interior of the Earth.—The phenomena above noticed have suggested the conclusion that the interior of the earth is in a fluid condition, and that, consequently, only to the depth of about thirty or forty miles is the crust of the earth solid.

It is argued that if the heat goes on increasing as the centre of the earth is approached, at the same rate as it does in mines, then at a comparatively shallow depth even the most refractory substances must necessarily be in a state of fusion.

Many scientific men, however, doubt the fluidity of the central mass, and admit the existence of only local seas and lakes of molten rock. They contend that, instead of being fluid, the interior of the earth, though intensely hot, is pasty, or even solid.

In justification of this view they argue that the enormous pressure exerted upon the interior of the earth would nullify the effect of its internal heat, because, if a substance is subjected to pressure, it cannot melt as readily as under ordinary circumstances. A body, therefore, may remain solid at a very high temperature, if it be under pressure. Of course, the condition of the successive layers that constitute the substance of the earth is, that while they are subjected to a heat which increases enormously as the centre is approached, they are at the same time subjected to a pressure which also increases enormously as the centre is approached.

Whether, however, we adopt the view that the central mass is fluid or solid, it does not affect the conclusion that it is in an intensely heated condition.

TOPICAL ANALYSIS.

IV. INTERNAL HEAT OF THE EARTH.

- **1. Evidences of Internal Heat.**
  - Mines. Increase of heat with depth. Means of mitigating the heat. Depth of mines.
  - Artesian Wells. Depth reached. Increase of temperature with depth. Distribution of such wells.
  - Hot Springs. Number and distribution. Temperature.
  - Geysers. Location. Most noted geysers. Geyser basins. Action of the geyser. Geysers of the Yellowstone.
  - Volcanoes. How they indicate internal heat.
- **2. Condition of the Interior of the Earth.**
  - Two views held. Arguments in favor of them. General conclusion.

TEST QUESTIONS.—Why can miners not work deeper below the surface than about 2,500 feet? Why should artesian wells be colder than mines, at the same depth? Why are rims formed round geyser basins? What force is it that drives out the water to such a height? What do we infer from the existence of geysers in any region?

V. VOLCANOES.

1. A Volcano is usually a mound, hill, or mountain, formed of materials thrown up from the interior of the earth. Its most important feature is the *crater*, a depression or hollow, shaped, as the name implies, like a vast bowl or basin. It is either upon the summit or upon the slopes of the volcanic mountain. Through a hole, or holes, in the bottom or the sides of the crater, the materials ejected find their way.

Example.—The crater of Kilauea, in Hawaii, is one of the most remarkable in the world. It is a vast oval basin about 1,000 feet deep, one mile wide, and three in length. Its floor is partly occupied by two lakes of molten matter in a state of violent ebullition. Fiery jets are sometimes thrown from the surface to the height of seventy feet.

2. Formation of a Volcano.—At the beginning of its existence, a volcano is simply a hole in the crust of the earth. Materials are ejected. These naturally fall around the sides of the vent, and form a circular mound. Successive eruptions occur. The mound becomes larger and loftier with each eruption, until in the course of centuries a mountain is formed. The vent remains low while the matter ejected is thus built up about it, and in this way the crater assumes its basin-like shape.

RAPIDITY.—The process of formation is sometimes very rapid. Jorullo, in Mexico, was thrown up in a single night to the height of 1,695 feet above the plain in which it stands. Monte Nuovo, a volcanic hill near Naples, was formed in the course of a few days.

SUBMARINE VOLCANOES.—The formation of a volcano may begin at considerable depths below the level of the sea. In proof of this it may be said that vast numbers of oceanic islands owe their existence to volcanic action, and deep-sea soundings show that many of the deepest parts of the ocean are covered with volcanic débris.

In 1831 a mass of matter rose from the sea near the coast of Sicily, and attained in a few weeks the height of 170 feet above the water. It was named Graham Island. In a few months it disappeared, because the materials composing it were so loosely held together. If the matter ejected by submarine volcanoes is compact, a permanent island is formed.

In the year 1790 a volume of steam was seen to arise from the sea about thirty miles north of Unalaska, one of the Aleutian Islands. Ejected materials gradually accumulated. The mass grew higher and higher, until now it is several thousand feet above the sea level, and has a circumference of two or three miles.

COTOPAXI.

THE FORM OF VOLCANIC MOUNTAINS is generally more or less conical. If the materials ejected are in a fluid state, the elevation is comparatively small. The volcanoes of the Sandwich Islands present the form of exceedingly flattened cones. This is because the matter which they emit is very liquid. When the materials are less fluid, the slopes are steeper, and the form of the mountain approaches that of a pointed cone.

A notable example is Cotopaxi. It is the most symmetrical of volcanoes.

THE HEIGHT OF VOLCANOES.—The highest volcano in the Old World is Kliutchev, in Kamtchatka. It is about 15,000 feet high. There are some in South America higher than this. Several among the Andes have an altitude of more than 20,000 feet.

3. The materials ejected from volcanoes are *steam, gases, mud, lava,* or molten rock, *stones, ashes, sand, and dust.*

LAVA is a mixture of various rocky substances. The most important of its elements is silica, which is familiar to us in the forms of white sand, quartz, and flint. Issuing from the volcano lava closely resembles the slag of a smelting furnace.

Formation of Lava.—It may be asked how we account for its fluid condition, if we suppose that the materials in the interior of the earth, though intensely hot, are still solid. The explanation is, that these solid but intensely heated materials, on being driven upward, are relieved from pressure, and assume the fluid state, even before reaching the surface.

When steam bubbles are imprisoned in molten lava in the act of cooling, the lava is converted into a light porous mass, which is the well-known substance called *pumice.*

Often the lava is completely reduced to powder, and it is then called *volcanic ashes,* or, if coarser, *volcanic sand.* Sometimes the wind blows the molten lava into delicate fibres like those of spun glass.[*] The Sandwich Islanders gave the name of "Pele's Hair" to this substance, Pele being the name of the goddess of the volcano of Kilauea.

VOLCANO OF SANTORINI (in Grecian Archipelago, active in 1866).

4. Quantity of Matter Ejected.—The quantity of lava and other matter emitted by volcanoes is immense. The lava that issued from Hecla in 1783 was computed by Sir Charles Lyell to be equal in volume to the water discharged by the Mississippi in three months.

In the eruption of Vesuvius, A.D. 79, the matter vomited forth far exceeded the entire bulk of the mountain; while in 1660 Etna disgorged twenty times its own mass.

In 1878 such quantities of pumice were thrown out from the volcano of the Solomon Isles into the surrounding sea, that it took ships three days to force their way through them. Sometimes one may even walk upon the floating pumice as upon a vast raft. [See "Krakatoa Eruption" in Recent Facts.]

5. Volcanoes Classified.—Volcanoes may be classified as active, dormant, or extinct. *Active* volcanoes eject various substances. When no signs of activity are given for a considerable time, the volcano is said to be *dormant.* When a volcano has been dormant for centuries, and it seems probable that its activity is lost forever, it is said to be *extinct.*

The frequency of volcanic discharges is varied. Some volcanoes are continuously active. Stromboli has been for 2,000 years in a state of constant, but not dangerous activity. It is visible at night to a distance of more than 100 miles all round. A red glow is seen from time to time above the summit of the mountain. This becomes gradually more and more brilliant, and then as gradually dies away. It is this phenomenon which has given to Stromboli[†] the name. "Lighthouse of the Mediterranean."

On the other hand, Cotopaxi and Tunguragua in the Andes have had eruptions only once in 100 years.

Vesuvius exhibits great irregularity. It had been long dormant before the eruption of A.D. 79. Its crater was nearly filled up, and was occupied by an abundant forest-growth. Cities and villages graced its slopes. After this eruption, none of great moment occurred until 1631. At that time, one of the most destructive on record took place. It continued for three months, and destroyed a number of cities and villages. The last eruption occurred in 1872.

From these and similar facts, it is evident that we have no knowledge of any law which governs the frequency of volcanic eruptions.

6. Eruptions.—There is no definite order in which the phenomena of an eruption succeed one another. They are usually preceded by subterranean rumblings and tremors. Before the great eruption of 1872, Vesuvius gave indications of unusual activity for a whole year. In many cases, however, the eruption follows the warning immediately. An eye-witness, writing of Stromboli, says that he had observed numerous light, curling wreaths of vapor ascending from the crater; then suddenly, without the slightest warning, a sound was heard like that of a locomotive giving off steam; and the eruption at once occurred.

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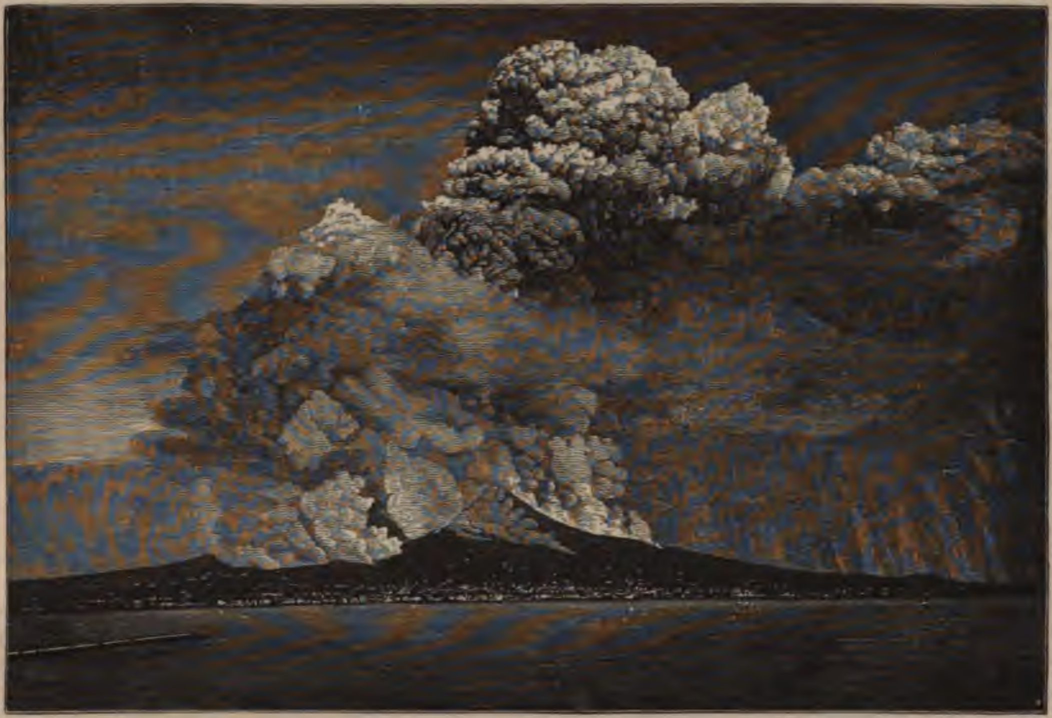
[*] A similar substance is artificially produced by directing a blast of air or steam into the slag of a smelting furnace. It is known in commerce as mineral wool.

[†] This fire, it should be observed, is really the reflection upon the vapor-cloud from the seething surface of the red-hot lava within the crater.

EMISSION OF STEAM.—In general, after the preliminary rumblings and tremors, dense columns and globular masses of *watery vapor* mingled with a variety of gaseous substances issue from the crater. According to the state of the atmosphere, and the existence of winds and air currents, the vapor assumes a variety of forms.

In the case of Mount Vesuvius it not unfrequently expands after attaining a certain height, and becomes like a vast "umbrella," as the Italians call it, having a top many miles in circumference. The lurid glare of the boiling lava in the crater below is reflected upon the under-surface of the umbrella, and gives the appearance of a vast conflagration. This spectacle is indescribably impressive at night. During the eruption of Vesuvius in 1872, instantaneous photographs were obtained of the umbrella. The above cut is a copy of one. From this, recollecting that Vesuvius is 4,000 feet high, we see that the vapor rose to the height of 20,000 feet, or nearly four miles.



VESUVIUS IN ERUPTION, AS SEEN FROM NAPLES, APRIL 26, 1872.

The vapor emitted, being condensed, falls as rain. The rainfall is excessive and long continued, and often gives rise to destructive floods. Around the vapory column vivid lightning constantly plays.

Jets of steam under high pressure, if allowed to issue from an orifice, give rise, in doing so, to large quantities of electricity. A machine has been constructed to generate electricity in this way. From it torrents of sparks as much as fourteen inches in length have been obtained. The crater, with its immense volume of uprising vapor, may be compared to a gigantic machine of this description.

EMISSION OF SOLID MATERIALS.—Often with the vapor are mingled immense quantities of volcanic *ashes and sand*, which descend and cover the surrounding country, sometimes to the depth of many feet.

Eighteen hundred years ago (A.D. 79), the cities of Herculaneum and Pompeii in Italy were covered with a deluge of ashes from an eruption of Vesuvius. They were buried from 70 to 120 feet, and lost to view for nearly seventeen centuries. In 1711, a well-digger turned up a bit of statuary, which led to the discovery of the two cities. The work of exhuming them is still going on.

The distance to which the ashes of a volcano may be carried is almost incredible. In 1845, the ashes of Hecla were carried to the Orkney Islands, a distance of nearly 700 miles, and in 1813, those of Tomboro, in the island of Sumbawa, fell at Bencoolen, 1,100 miles away.

Rocks and stones are sometimes vomited forth with fearful noise, and hurled with prodigious force. A mass of rock, measuring 300 cubic feet, was on one occasion thrown from Cotopaxi to a distance of about eight miles.

THE EMISSION OF LAVA in the molten state is the most imposing of volcanic phenomena. The action which goes on has been compared to that which occurs in a pot of boiling porridge.

Explanation.—As the mass of porridge gets hot, steam is generated in it at the bottom. This rises through the porridge. In doing so it forces a portion upward. More and more steam being generated, bubbles of porridge rise to the surface, and mimic explosions occur, or the porridge is thrown in little jets above the surface of the boiling material. The process may increase in violence until the phenomenon of boiling-over takes place. Quite similarly the boiling lava is forced upward higher and higher in its crater by vast volumes of steam that are seeking to escape. Explosions occur on the boiling surface, and often jets are thrown far up into the air.

Finally, the rising lava overflows the rim of the crater, or quite as often bursts through the sides of the mountain, and pours down its slopes in rivers of fire.

So numerous were the fissures which rent Vesuvius in the eruption of 1872 that liquid lava seemed to ooze from every portion of it, and, as an eyewitness expressed it, "Vesuvius sweated fire."

LAVA STREAMS vary in magnitude. The largest recorded were those of Skaptar Jökul, in Iceland, in the years 1783–5. Torrents of molten rock deluged the island. River-courses, ravines, and lakes were filled, and the surface of the country for hundreds of square miles was completely devastated. Some of the streams were about fifty miles in length, and in certain places fifteen miles in breadth, and 100 feet deep. In some of the narrow valleys the depth was 600 feet.

The velocity of the streams, and the distance to which they reach, depend on the fluidity of the lava, and the slope of the land. One thousand feet per hour is a rapid rate; the extreme of ten thousand feet per hour has been observed, though rarely.

The retention of its heat by a lava-stream is very remarkable. When the surface of the stream has cooled, it becomes a hard crust which prevents the escape of the heat.

A mass of lava 500 feet thick, ejected from Jorullo in 1759, was seen smoking by Alexander von Humboldt forty-five years after. The Indians lit cigars at its crevices. The lava thrown from Vesuvius in 1858 continued as late as 1873 to give out steam, and remained so hot that one's hand could not be held in some of the fissures for more than a few seconds.

END OF ERUPTION.—The flow of the lava is the beginning of the end. After its occurrence the showers of ashes gradually cease, the explosions become less and less frequent, and at length no evidence of volcanic activity remains, save perhaps a vapor-cloud veiling the summit of the mountain.

7. *Distribution of Volcanoes.*—Two significant facts are to be observed regarding the distribution of volcanoes.

First: *the active volcanoes of the globe are,* as a rule, *situated upon areas which are undergoing upheaval.* Those portions of the surface of the earth which are subsiding are without volcanic activity.

Second: *almost all volcanoes are near the sea.* Those upon the continents are close to the shores. The only well-authenticated examples of volcanoes situated far inland, are those of Ararat and Demavend, of Peshan and Turfan, or Hot-Scheou, and the Solfatara of Urumtsi, all in Central Asia.

The most striking exemplification of this law of volcanic distribution is presented by the Pacific Ocean. It is literally encircled with active volcanoes.

THE GREAT VOLCANIC BELTS.—There are three great belts traversing the globe, within which nearly all the volcanoes of the world are situated. These may be called the Pacific Insular Belt, the Atlantic Insular Belt, and the American Continental Belt. [See map on opposite page.]

The Pacific Insular Belt extends all along the northern and western shores of the Pacific Ocean. Beginning with the Aleutian Islands it embraces Kamtchatka, the Kurile, Japanese and Philippine Islands, Sumatra, Java, New Guinea, the Friendly Islands, and New Zealand.

One extension of this belt embraces the Society, Marquesas and Sandwich Islands; another is the volcanic region of Victoria Land.

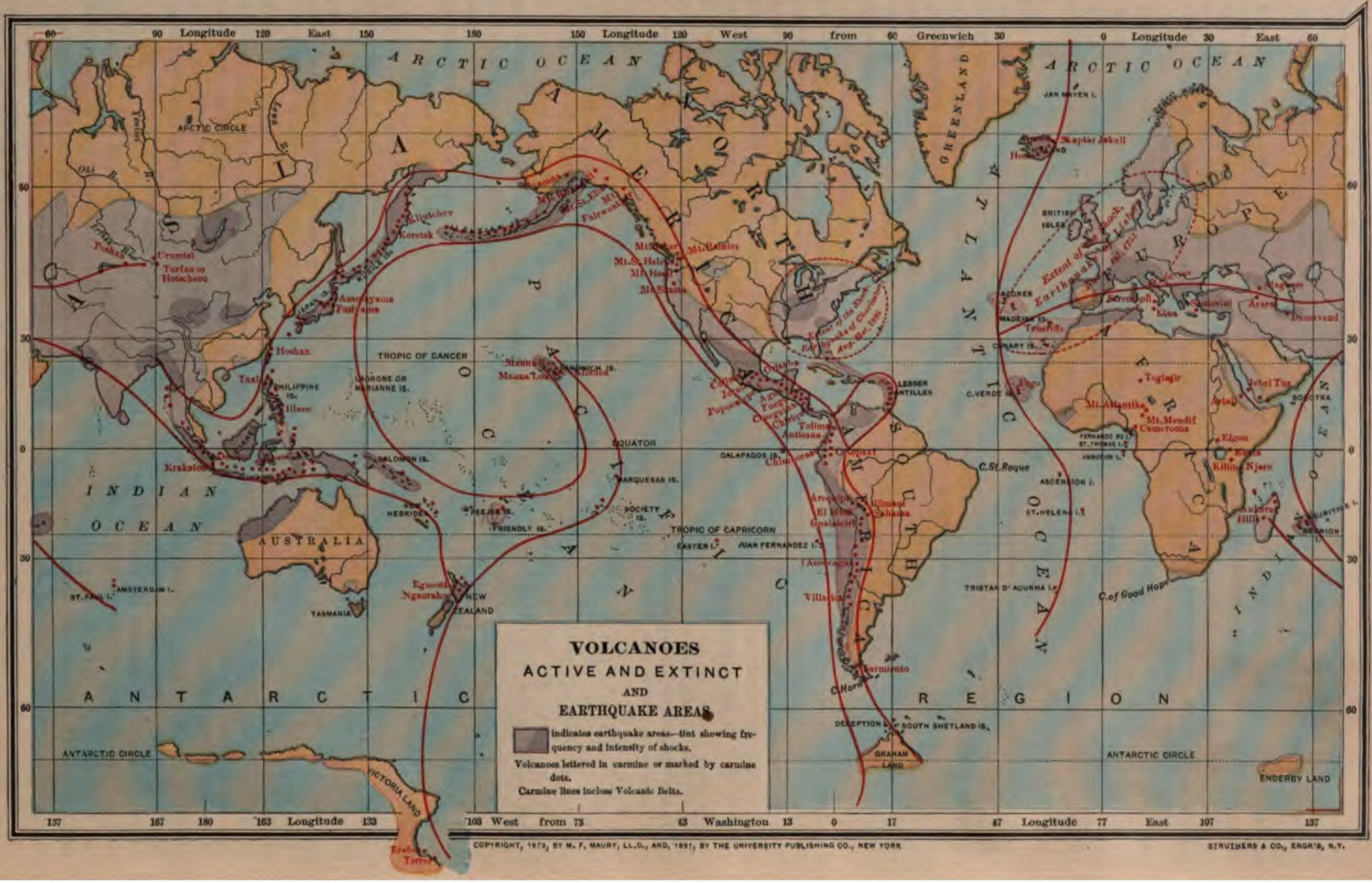
The Atlantic Insular Belt comprises extinct and active volcanoes and volcanic islands which traverse the Atlantic from north to south. The Islands of Jan Mayen, Iceland, the Azores, Cape Verd Islands, St. Helena, and Tristan d'Acunha, are points which mark this volcanic band.

The American Continental Belt.—The third great volcanic belt is mainly continental. It extends from Cape Horn and the South Shetland Islands to Alaska, a distance of more than 10,000 miles. All along this line volcanoes, singly or in groups, are found. An outlying spur of it includes the Lesser Antilles.

A minor, yet very important volcanic belt is that of the Mediterranean region. It comprises Etna, Vesuvius, Stromboli, and Vulcano in the Lipari Islands, and Santorini and Nisyros in the Ægean Sea.

Outside of the three great belts there are many volcanoes irregularly distributed. In the Pacific all islands not of coral origin are composed of volcanic rocks. In the Indian Ocean there are volcanoes upon Madagascar and the adjacent islands.

In Central France, in Spain, and generally throughout Europe, there are numberless proofs of volcanic action. Africa is thought to contain about ten volcanoes. The volcanoes most remarkable for the irregularity of their situation are those in Central Asia already mentioned.



VOLCANOES
ACTIVE AND EXTINCT
AND
EARTHQUAKE AREAS

▨ indicates earthquake areas—tint showing frequency and intensity of shocks.

Volcanoes lettered in carmine or marked by carmine dots.

Carmine lines inclose Volcanic Belts.

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THE NUMBER OF ACTIVE VOLCANOES on the surface of the globe is estimated at from 300 to 350. Of dormant and extinct about 700 are reckoned.

8. ***The most active Volcanic Region*** in the world, at present, consists of the islands in the Malay Archipelago. Java is the centre of it. No region is so thickly studded with burning mountains as this island. It has twenty-one volcanic cones.

In 1772 one of them was in violent eruption. Its immense cone actually disappeared. It carried down with it ninety square miles of land, and forty villages were swallowed up.

In 1815, Tomboro, on the island of Sumbawa, 300 miles from Java, burst forth with such violence, that the explosions were heard at the distance of 970 miles.

9. ***Causes of Volcanoes.***—The fundamental cause of volcanic action is undoubtedly the expansive force of compressed steam and other gases. Two cases are conceivable: (1) the compressed steam and gases may be free, *i. e.* not blended with the lava; or, (2) they may be imprisoned within the substance of the lava. The force developed will be the same in both these cases, but the mode of action will be somewhat different. Let us consider the first case.

ACTION OF FREE GASES.—Bear in mind that at a comparatively shallow depth the earth is intensely hot. Then observe [see p. 13, Artesian Wells] that water may readily find its way through crevices or between the strata of rocks, and come into contact with the heated matter. The effect will be to convert a part of the inflowing water into steam. This may be done with great suddenness.

The same conditions will occur as those which often cause the explosion of a steam boiler. The water in the boiler gets low, the fire is kept up, and the walls of the boiler become intensely heated. If now there be a sudden influx of water, some of it is converted into steam with such rapidity and in such quantity that it cannot possibly escape. The boiler is unable to resist the pressure, and an explosion takes place.

Similarly the water that finds its way into the intensely heated interior of the earth may be suddenly converted into steam. The expansive force of the steam increases under the two influences of enormous heat and enormous pressure.

Suppose the water to enter some subterranean cavity partly filled with molten lava. Steam is suddenly generated and an explosion occurs. By the concussion, the fissure which admitted the water is closed, and the remaining water completely pent up. It is converted into steam. Heavy pressure and intense heat give to it enormous expansive power. We can imagine how such superheated steam might drive upward lava, or stones and sand. It would act on exactly the same principle as that of the compressed air the air-chamber of a force pump or a water-ram.

ACTION OF ABSORBED GASES.—The second case in all probability occurs more commonly than the first, and in fact, it seems to contain the explanation of nearly all the phenomena of volcanic eruptions. A number of substances, solid and liquid, absorb, under pressure, and at high temperatures, many times their own volume of steam and other gases. If the temperature be reduced, or the pressure be relieved, these gases can no longer be retained in absorption. They escape with explosive violence. Lava, intensely heated and under pressure, absorbs many times its volume of steam and other gases. Imagine it thus charged to be forced upward through the crust of the earth. Its capacity for retaining gases in absorption is diminished. The liberated gas expands and forces the lava in whatever may be the direction of least resistance, precisely as the volume of gases liberated from gunpowder and similar substances expands and forces obstacles before it with explosive violence.

Among other things this satisfactorily explains the pulverization of lava and the production of volcanic sand. The gases absorbed by the lava being relieved from pressure, blow it into powder, as wood is blown to pulp for making paper.

Some writers consider that volcanoes are due to the shrinkage of the crust of the earth compressing and forcing upward molten matter from subterranean regions. Steam, however, is admitted to be the only agency which accounts for the explosive character of eruptions.

TOPICAL ANALYSIS.

V. VOLCANOES.

1. Description.
Principal feature. Crater of Kilauea

2. Formation.
Mode. Rapidity. Submarine volcanoes. Form of volcanic mountains. Height of volcanoes.

3. Materials ejected.
Lava. Formation of. Pumice. Volcanic ashes and sand. Pele's hair.

4. Quantity of matter ejected.
Examples.

5. Volcanoes classified.
Frequency of discharge. Examples.

6. Eruptions.
Phenomena of. Appearance of flame, how produced. Cause of lightning. Emission of solid materials. Emission of lava, how produced. Lava-streams, magnitude and velocity of. Retention of heat by. End of eruption.

7. Distribution of volcanoes.
In relation to change of level of surrounding area. In relation to the sea. Great volcanic belts. Pacific Insular. Atlantic Insular. American Continental. Minor belt. Irregularity of distribution. Number of active volcanoes.

8. Most active volcanic region.
Situation.

9. Cause of volcanoes.
Conceivable cases. Action of free gases. Action of absorbed gases.

Test Questions.—In what way would you suppose the number of active volcanoes to be changing, and why? What volcano is nearest to the place where you live?

VI. EARTHQUAKES.

1. An Earthquake *is a shaking or trembling of some part of the crust of the earth.* It is *a vibratory* or *wave-like motion* resembling the ground-swell or roll of the sea. It may be nothing more than a slight tremor like that made by a loaded wagon passing along a street, or it may be such a violent movement as to destroy whole cities.

Usually, at the commencement of an earthquake, a rumbling noise, like distant thunder, deep down below the surface of the earth, is heard travelling along, as if in search of some weak place through which to burst. Then suddenly, without any warning, the ground rises and falls, houses rock to and fro, until they are rent from top to bottom, or fall with a crash into ruins. In some cases the earth opens with gaping cracks which either close again or are permanent. In a few seconds a city may be demolished, and hundreds or thousands of its inhabitants may be dead or dying.

The origin of the vibratory motion or *earth-wave* is called the *centre* or *focus.* It is not a point, but a fissure or space between great masses of rock. It is believed that it is rarely more than thirty miles below the surface.

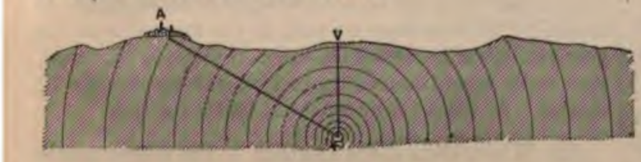


Diagram illustrating the propagation of an earth-wave from F, the focus. V is a point where the shock is vertical; A, a town where the shock is felt. If we know A V, the distance between A and V, and the direction of the shock at A, we can compute V F, the depth of the focus.

From the focus the earth-wave is *propagated* in all directions. While, however, this is generally true, it must be observed that the transmission of the vibration will necessarily depend on the nature of the materials encountered. In some directions, perhaps in many, the earth-wave will meet with such obstacles that it will rebound, and practically be nullified, like a wave of water dashing against a rock.

The velocity of the earth-wave appears to be, on an average, about twenty-five miles a minute. It may attain the enormous speed of five or six thousand miles an hour.

2. Duration of Earthquakes.—Earthquakes may be momentary; or they may consist of several successive shocks; and these may be repeated during long periods. After the earthquake, which, in 1766, destroyed the city of Cumana, in Venezuela, shocks were felt nearly every hour for fourteen months.

In St. Thomas, after the earthquake of 1867, and at Charleston, after that of 1886, shocks were felt for many weeks.

3. Area of Disturbance.—The area through which the disturbance extends may be very large. The shock of the earthquake of Lisbon, in 1755, was definitely felt as far as Finland in one direction, and as far as Madeira in another. [See map, page 19.]

The disturbance affected the sea to a much greater distance. The water rose among the West India Islands so that Antigua, Martinique, Guadeloupe and Barbadoes were overflowed. The area disturbed was four times as great as that of Europe.

In 1783, all the towns within a radius of twenty miles from the town of Oppido, in Calabria, were destroyed.

The great earthquake of Guadeloupe, in 1842, was felt through an area of not less than 3,000,000 square miles; that of Charleston through a nearly equal area.

In shape, the area of disturbance is commonly an irregular oval.

4. The Sea-Waves which are caused by earthquakes that have their centre under the ocean bed, are appalling phenomena.

The water at first recedes from the beach, and exposes the sea-bed even beyond the usual limits of low water. Then the sea-wave comes in with a steep front or wall sometimes more than fifty feet high. It drives back the receding water, and deluges the shore, sometimes demolishing whole towns. It often passes inland to the distance of several miles. The inhabitants rush to the hills, and remain there until the wave subsides.

Examples.—The great wave of the Lisbon earthquake was sixty feet high at Cadiz. It rose and fell eighteen times at Tangier, in Africa.

In 1854, when Simoda, in Japan, was destroyed by an earthquake, the sea-wave completely overwhelmed the place. The receding wave actually crossed the Pacific, and made the water rise on the coast of California.

In 1746, the town of old Callao, in Peru, was destroyed by an earthquake. A wave 80 feet high tore from her anchors a Spanish man-of-war, lifted her over the houses, and carried her several miles inland. The receding wave left her high and dry on the road to Lima.

Sea-waves are often perceptible throughout an entire ocean basin. They travel across the Pacific at the rate of about 350 miles an hour.

If the centre of the earthquake is on land, so near the coast as to disturb the sea, the waves produced are thrown out from the shore and are harmless. This explains why, although the Charleston earthquake was felt at sea as far as the Bermudas, no wave-damage was done in the harbor of Charleston.

5. *Destructive Effects.*—Earthquakes are perhaps the most impressive manifestations of power in the material world. The destruction of human life occasioned by them is appalling.

On the 1st of November, 1755, Lisbon was shaken by the "great earthquake," and in six minutes its palaces were in ruins, and 60,000 of its inhabitants were dead.

In March, 1812, Caracas, in Venezuela, was destroyed, with 10,000 of its inhabitants.

6. *Upheavals and Depressions.*—Geological changes of great importance often accompany earthquakes.

In the year 1819 an earthquake occurred in the region adjacent to the mouth of the Indus. It completely destroyed the town of Bhooj, and was felt within a radius of hundreds of miles. A tract to which the natives gave the name of "Allah Bund," or "Mound of God," was raised where, before, there had been a level plain. The "Bund" was fifty miles long, sixteen miles wide, and about ten feet high. At the same time the fort and village of Sindree, with the neighboring region, subsided; the sea flowed into the sunk area, and an inland sea was formed covering 2,000 square miles.

7. *Distribution of Earthquakes.*—*No part of the earth is entirely free from earthquakes.* In certain parts of Japan tremors are felt every day. Vessels not unfrequently report earthquake shocks at sea.

In the OLD WORLD they are most frequent in a region which embraces the northern shores of the Mediterranean Sea, and extends eastward into the central portions of Asia.

In the NEW WORLD earthquakes are far more common than in the Old. Both the eastern and western mountain regions of North America are subject to them, but the region of greatest frequency is in South America. It comprises Ecuador, Peru, and Chili.

In many places within this region the houses are built of reeds and bamboo, lashed by thongs of bull's hide, and secured in their places with cords instead of nails, that they may yield to the shocks without being shaken to pieces.

The natives can feel the approach of an earthquake long before the stranger can. Suddenly, in the midst of gayety, the author has heard the cry, accompanied by shrieks, "Tremblor!" [*earthquake*]. Then a rush for the streets. Sometimes, when these alarms take place in the dead of night, the whole population may be seen out in their night-clothes, kneeling and praying in an agony of terror.

8. *Causes of Earthquakes.*—Various causes have been assigned to account for earthquakes. Many have referred them to volcanic action; but they are probably due for the most part to what is known as "displacement."

(1) By this is meant the sliding of vast masses of rock one upon another. When the millstones in a grist mill are in motion, the whole building is in a state of vibration or tremor. The vibrations are more or less violent according to the size and number of the stones. And in like manner the noise or rumbling produced will vary. Now imagine that, from any cause, masses of rock millions of times the size of the millstones should slide or grind upon one another. Clearly rumblings and tremors would be occasioned. We can imagine the tremors produced by the sliding of vast rock masses to be so violent as to produce the destructive effects of earthquakes.

But can any cause be conceived for the displacement supposed? It is believed that the cooling and contraction of the interior of the earth account for it. The inner strata or layers of rock, as they cool and contract, shrink away from the outer layers. Then some portions of the outer layers are left without support. They may now bend or they may break. Having broken, they may slide and grind upon the rocks that lie underneath. The effects of such sliding may be faintly illustrated by the jarring and noise produced by millstones in motion, or by a heavy body of snow when it slides upon the roof of a large church.

If reference be made to page 28, it will appear that the same causes which are believed to occasion earthquakes are considered to have been at work in the formation of the grand mountain systems of the earth. If this view be correct, then where mountain-making goes on, earthquakes should abound. And this has always been, and is the case.

(2) While thus displacement is the direct cause of earthquakes in general, it is probable that certain earthquakes, which have been termed "explosive," are due to volcanic action, as their ***indirect*** cause. These are of minor importance and are local in their effects.

9. *Relation of Earthquakes to Volcanoes.*—A close relation exists between earthquakes and volcanoes. Displacements are the direct *cause* of earthquakes, and they are *conditions* which at least contribute to the production of volcanic action. Hence it is that earthquakes are most frequent in volcanic regions.

Moreover, aside from what is noted above in paragraph (2), volcanic action may aid in the production of earthquakes by removing matter from the interior of the earth, and depositing it upon strata already under strain. This would contribute to displacement, and so to earthquakes.

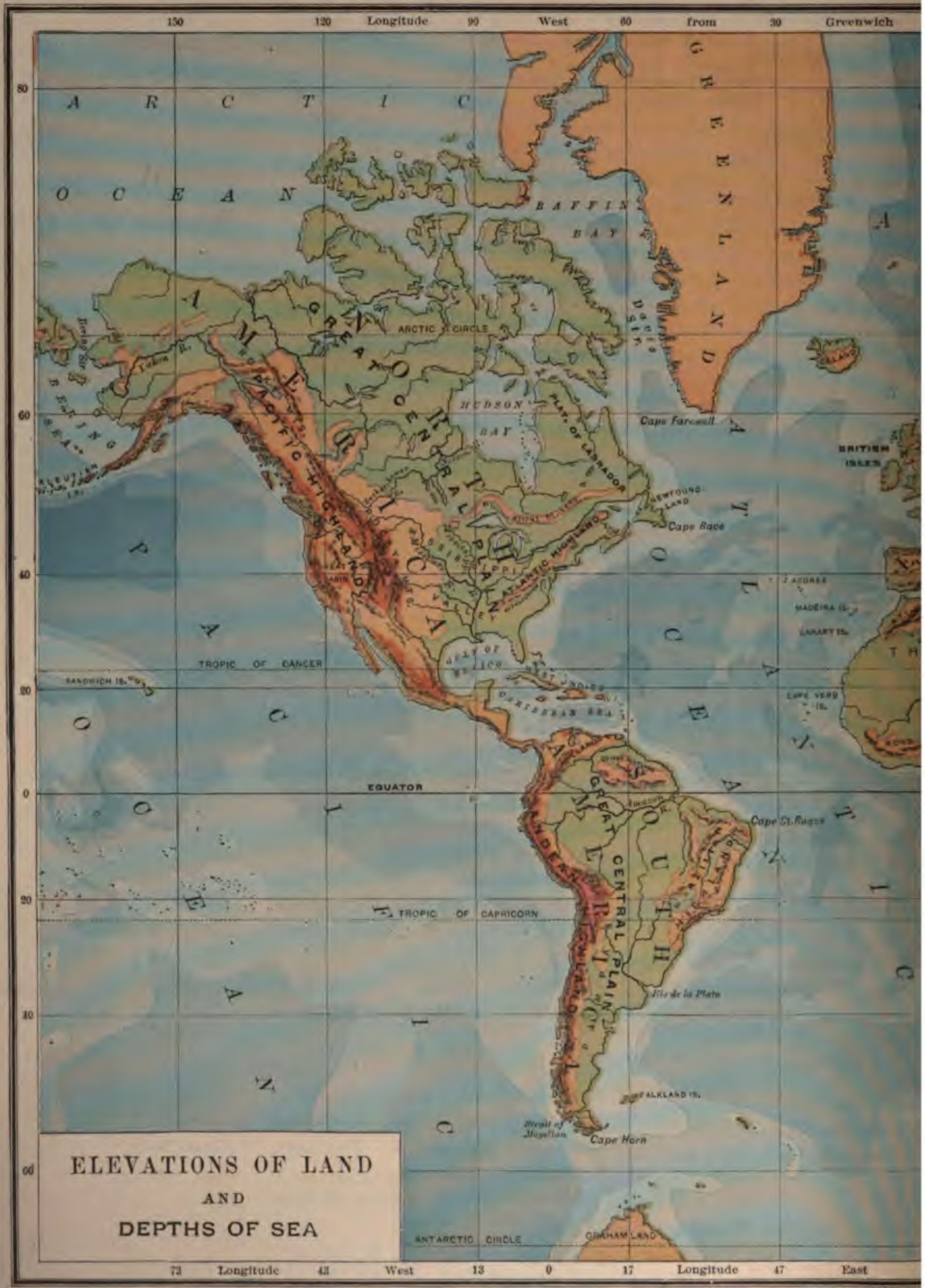
TOPICAL ANALYSIS.

VI. EARTHQUAKES.

1. **Description.**
   Characteristic phenomena. Origin of vibratory motion of earth-wave. Velocity of.
2. **Duration.**
   Examples.
3. **Area of Disturbance.**
   Examples.
4. **Sea-Waves.**
   Description. Examples.
5. **Effects.**
   Destruction of human life.
6. **Upheavals and depressions.**
   Examples.
7. **Distribution.**
   In general. In the Old World. In the New.
8. **Causes of Earthquakes.**
9. **Relation to Volcanoes.**
   As to locality, cause and time of occurrence.

TOPICAL ANALYSIS FOR REVIEW.

The Earth as a Planet . . .	What is the Earth ? Ancient Theory. Copernican. The Solar System. The Sun. Planets. Nebular Hypothesis. Actual size of the Earth. Comparative Insignificance.
The Planetary Movements. .	Effects of the Earth's Motions. Rotation. Revolution. Inclination of Planetary Axes. Results. Adaptation of the Earth for Human Habitation.
Magnetism of the Earth . .	How Demonstrated. Magnets. Natural. Artificial. Properties of the Magnet The Earth a Magnet. Inclination of the Needle. Declination of the Needle. Magnetic Storms. Sun Spots and Terrestrial Magnetism. Cause of Terrestrial Magnetism. Uses of.
Internal Heat of the Earth .	Evidences of. Mines. Artesian Wells, Hot Springs, Geysers, Volcanoes. Condition of the Interior of the Earth.
Volcanoes	Description of. Formation of. Rapidity. Form. Materials Ejected. Kinds. Quantity. Eruptions. Most Common Phenomena. Lava-streams. Distribution of Volcanoes. Two Laws. Volcanic Belts. Most Active Region. Causes of Volcanoes. Action of Gases.
Earthquakes.	Description. Duration of Earthquake. Area of Disturbance. Sea Waves. Destructive Effects. Upheavals and Depressions. Distribution of Earthquakes. Causes of Earthquakes. Relation to Volcanoes.



ELEVATIONS OF LAND
AND
DEPTHS OF SEA

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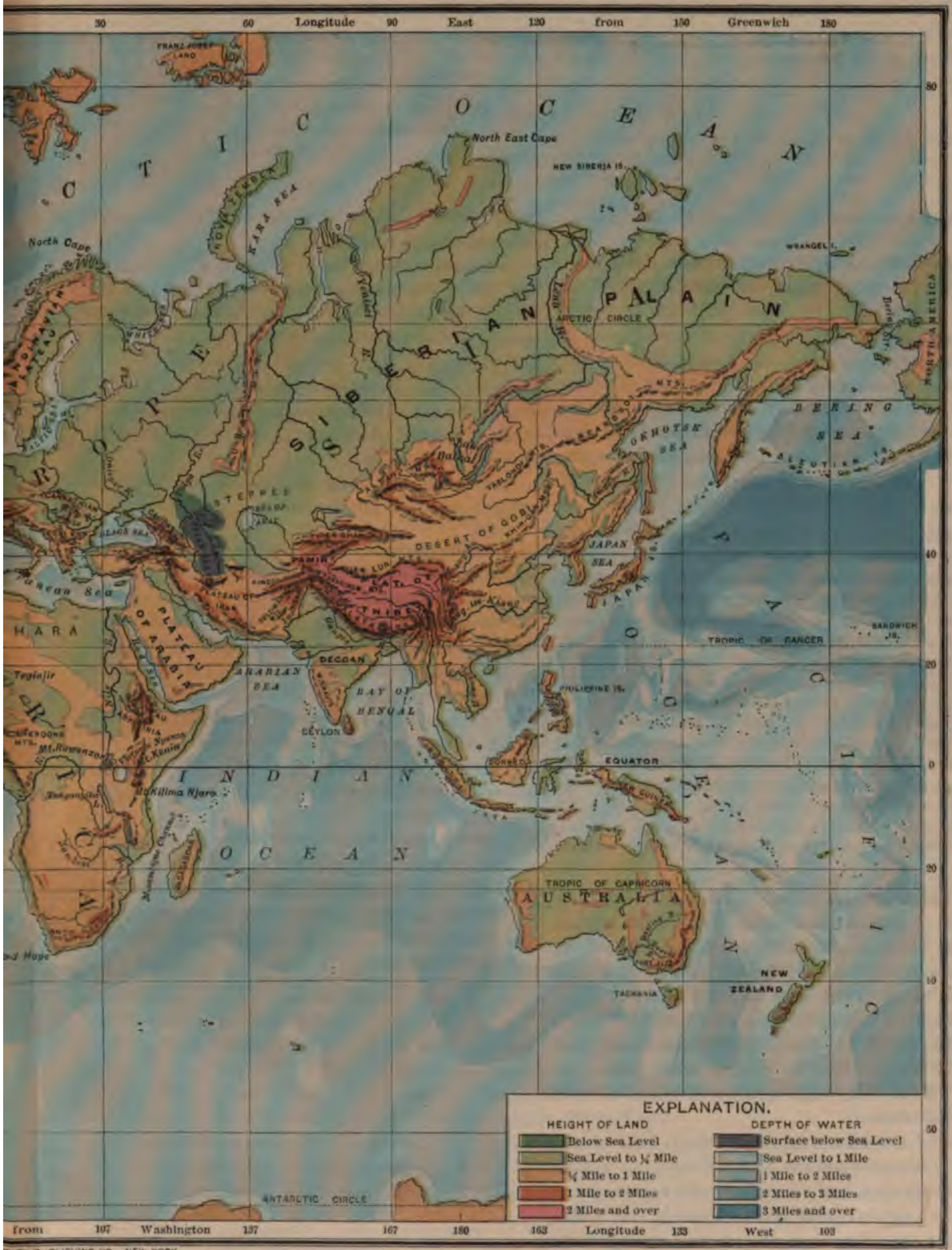

EXPLANATION.

HEIGHT OF LAND	DEPTH OF WATER
Below Sea Level	Surface below Sea Level
Sea Level to ¼ Mile	Sea Level to 1 Mile
¼ Mile to 1 Mile	1 Mile to 2 Miles
1 Mile to 2 Miles	2 Miles to 3 Miles
2 Miles and over	3 Miles and over

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PART II.

THE LAND.

I. ARRANGEMENT OF LAND MASSES.

1. Relations of land, water and air. —In the preceding pages we have regarded the Earth as a whole. In those which are to follow we shall consider (1) the various constituents of the earth, viz., the land, the water, and the air; (2) the phenomena which belong to each of these; and (3) the life which they support.

The land, the water, and the air are to be considered as parts of a grand and most perfect mechanism. They contribute in a variety of ways to the maintenance of plant and animal life.

Without a knowledge of Physical Geography we look upon the earth and its diverse agencies, as the young apprentice may be supposed, when he first enters the machine-shop, to look at the various parts of the steam engine which he sees there lying about, but ready to be put together. There they are, all the different parts, fly-wheel and crank, piston, valve and ratchet, steam-chest and boiler. Though they have so little resemblance to each other, and look so little like a compact and powerful machine, yet, when he comes to see them put together, to have the fires lighted, steam raised, and the engine started, he discovers at once that each part is made to fit into another and work with its fellow; that the whole is according to *design*, and that every piece has a special office to fulfil, failing in which the whole machine would be thrown into confusion. So it is, as the study of our science will show, with the terrestrial machinery.

2. Distribution of Land.—Of the 197,000,000 of square miles which embrace the surface of the earth, about 144,000,000 are covered by water, and 53,000,000 by land. In other words, there is nearly three times as much water as land.

The land is found in masses of irregular shape and size, which are separated by intervening portions of water. The six largest land-masses are called *Continents*. The smaller divisions of land are called *Islands*.

Most of the land is in the northern half of the globe. It surrounds the North Pole in an almost continuous ring, and from the polar regions it extends in long irregular masses towards the south. We may consider these masses as forming three pairs of continents. The division comprising North America and South America affords the most perfect example of this arrangement; that consisting of Europe and Africa is less well defined; while that is most irregular which comprises Asia and Australia.

In regard to *shape* the continents follow a general law. They spread out broadly towards the north, while towards the south they taper to points, or throw out peninsulas. Thus, in general, they approach the form of a triangle. This is strikingly illustrated in the case of Africa and the two Americas. Europe and Asia combined form a vast triangle. Australia is the only marked exception to the rule.

Almost all the large peninsulas are southern projections from the continents.

3. Northern and Southern Hemispheres.—The globe is divided by the Equator into a Northern and Southern Hemisphere. North America, Europe, and Asia, two-thirds of Africa, and a portion of South America are contained in the Northern; Australia, part of Africa and the greater part of South America, in the Southern. There is three times as much land in the Northern as in the Southern Hemisphere.

The Northern Hemisphere is the seat of knowledge, civilization and power. It is the commercial hemisphere.

The Southern Hemisphere has never been the seat of power. The Peruvians and the Javanese were the only nations which attained a high degree of civilization there. Only about one-fifteenth of the population of the globe have their home within this hemisphere.

4. Land and Water Hemispheres.—The earth may be divided into two hemispheres, one of which contains nearly all the land, and the other nearly all the water. These hemispheres are known as the Land Hemisphere and the Water Hemisphere. London is nearly at the centre of the Land Hemisphere; New Zealand nearly at that of the Water Hemisphere. Australia presents the largest extent of land in the Water Hemisphere.

TOPICAL ANALYSIS.

I. ARRANGEMENT OF LAND MASSES.

1. **Relation of land, water and air.**
   Design in creation.

2. **Distribution of land.**
    Extent of land and water. Continents. Islands. Location and arrangement of the land. General form of the continents.
3. **Northern and Southern Hemispheres.**
    Dividing line. Continents in each. Proportion of land and population in the two hemispheres. Of civilization and power.
4. **Land and Water Hemispheres.**

QUESTIONS ON MAP OF THE WORLD.—How do Europe and Asia compare in general direction with North and South America? Which of the Old World continents resembles the New in general direction? What zones are traversed wholly or in part by each of the continents? What is the general direction of the mountain ranges of the Eastern Hemisphere? Of those of the Western? What islands are near the centre of the land hemisphere? What islands are near the centre of the water hemisphere?

II. FORMS OF LAND.

1. Horizontal Forms.—In horizontal form the various land-masses are very irregular. Everywhere the sea more or less deeply indents the shore. The indentations form navigable seas or sounds, harbors or roadsteads. The length and indentation of the shore line, therefore, are indications of the commercial capabilities of a continent.

Comparing the several continents, we find that the southern have far more regular outlines than the northern. Their indentation is comparatively limited, and their coast-line short. The contrast is most marked between Europe and Africa.

Europe has six times more coast-line in proportion to its area than Africa. The effect of this has been very important in the history of the two continents. By the multitudinous seas, bays, and gulfs of Europe inter-communication of one part of the continent with another, and with other portions of the world, has been facilitated, and thus its several countries have been rendered accessible to commerce and civilization. Europe has enjoyed among the continents the leadership in commerce.

Africa, on the other hand, with its comparatively unbroken coast-line and scanty harbors, has been barred by nature from extensive intercourse with the outside world.

North America, though in a less degree than Europe, is pre-eminent for the indentation of its sea-coast. This contributes to render it the companion of Europe in commerce and civilization.

2. Vertical Forms.—By vertical forms we mean the elevations of the land above the sea-level. With very insignificant exceptions all the land is more or less raised above the water.

THE AVERAGE ELEVATION of the earth's surface is not great. It has been estimated that if all the mountains were levelled, and all the valleys filled up, the land of the globe, taken as a whole, would not be raised, on an average, as much as 1,000 feet above the sea.

Although the mountains are so massive in size, and reach so far into the blue ether that their highest peaks can never be scaled; yet, when compared with the size of the earth, their huge proportions dwindle into insignificance.

A mountain five miles high, which is higher than any but the loftiest peaks of the Himalaya or Karakorum, rises above the sea-level but $\frac{1}{800}$ part of the earth's radius. Hence upon a globe sixteen inches in diameter, it would be represented by an elevation of only $\frac{1}{100}$ of an inch, about the thickness of two leaves of this book.

On a globe sixteen feet in diameter, the highest mountains would rise above the surface less than the eighth of an inch.

3. Forms of Relief.—According to their relief, the various forms of land are classified as lowlands or highlands.

Lowlands are elevated less than 1,000 feet above the sea. They are commonly called plains.

Highlands have an elevation of 1,000 feet or more above the sea. They are called plateaus or table-lands and mountains. There is no uniformity in the use of the term hill. It commonly designates an elevation of less than 2,000 feet.

4. Plains are those portions of the earth's surface which are level, or which, though diversified with hills, have only a moderate elevation above the sea-level. About half the extent of the continental surfaces consists of plains. If covered with grass, but generally destitute of trees, they are called *prairies* in our country, *pampas* or *llanos* in South America, and *steppes* in Asia. The densely wooded plains of the Amazon are called *selvas*.

Plains are classified according to their origin as *marine* or *alluvial*.

MARINE PLAINS are considered to have been, at some remote period in the history of the globe, portions of the floor of the sea. Upon them are found sometimes saline deposits, sometimes the remains of animals and plants that must have lived in salt water. Our own Atlantic seaboard and the Caspian region in Asia are noted examples of marine plains.

ALLUVIAL PLAINS are those which have been formed from materials washed down from the hills and mountains by the rain and the rivers. The Delta* and valley of the Nile, the Delta of the

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* The term Delta was originally applied to the deposit formed at the mouth of the Nile, and enclosed by its two main outlets. The area thus formed was triangular like the Greek letter Δ (*delta*), and hence the word has been applied in a general sense to alluvial lands at the mouths of rivers.

Mississippi, the plains of the Indus and the Ganges, and the Black Lands of Russia are alluvial. Such plains are among the most productive portions of the surface of the earth.

The Nile Valley and that of the Menam in Siam are annually overflowed, and covered, when the flood subsides, with a fine sedimentary deposit. This consists of rich fertilizing materials brought down from distant mountain slopes. It imparts perennial fertility. It has clothed the land of Egypt with verdure since the days of the Pharaohs, 3,000 years ago. It secures the great rice-crop of Siam.

Plains, centres of civilization.—Owing to their fertility and ease of cultivation, plains have been, throughout the history of man, centres of population, civilization, and power. The imperial glory of Nineveh and Babylon, the culture of ancient Egypt, the enduring prosperity of China, and the unrivalled wealth of India, all owe their origin to the treasures brought down from the everlasting hills.

5. Plateaus or ***Table-lands*** are broad elevated areas which rise above the level of the surrounding surface. The name suggests that they are flat. And some, indeed, as the Llano Estacado of Texas, are as level as the prairies. *Generally,* however, *they present a surface highly diversified.* Great mountains are often piled up upon them.

The plateau of Thibet consists of grassy plains and wide basins, often containing large lakes, engirdled by ranges of gigantic snow-clad mountains.

The aspect presented also by the great plateau lying between the Rocky Mountains and the Sierra Nevada in our own country, is that of a vast uplifted mass from which the mountains rise; while the plateau of Titicaca, in South America, with the towering peaks of the Andes embosoming its upland lake, singularly resembles the plateau of Thibet.

In elevation plateaus vary greatly. Low plateaus, like the desert of Sahara, are from 1,000 to 3,000 feet in height. The loftiest in the world are those of Thibet, 10,000 to 15,000 feet high, and Titicaca, about 12,000.

Plateaus unproductive.—The plateau regions of the world are for the most part unproductive. Many of them are absolute deserts. Hence few plateaus have ever become centres of population and power. It is interesting, however, to observe that the table-lands of Mexico, Peru, Titicaca and Thibet have each been the seat of a civilization peculiarly its own.

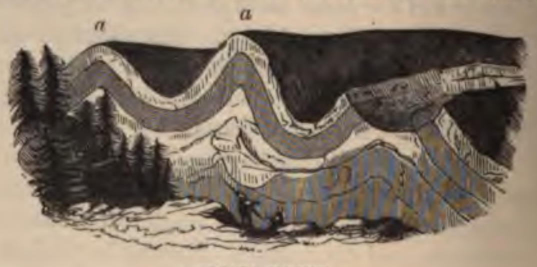
The desert plateaus have undoubtedly their part to perform in the economy of nature. They are not wastes in the sense of being wasted or useless areas. Their effect upon the rainfall and its distribution is most important. It will be more fully considered when we treat of the moisture of the air. [See p. 89.]

6. Mountains are elevations rising above the general level of the land to the height of 2,000 feet or more. Sometimes they stand singly, like Etna or Vesuvius, but are generally joined one to another and form a connected series. Such a series is called a *mountain chain* or *range.* The top of the chain is called the *crest.*

Mountain chains are seldom solitary. Usually two or more are parallel, or nearly parallel, with one another, forming what is called a *mountain system.* The Andes, the Alps, and the Appalachians are examples. In all of these there is not simply one long line of mountains, but a number of associated and nearly parallel ranges.

THE FORMATION OF MOUNTAINS is a subject which properly belongs to geology. It is generally considered that mountains have been formed mainly by two processes: (1) what is commonly called the crumpling of the surface of the earth; (2) the action of volcanic vents. The latter of these has already been sufficiently discussed in treating of the formation of volcanic cones. [See p. 15.] The former requires some explanation, since the great mountain systems of the world are thought to be due to it.

The crumpling or *folding process.*—Suppose the earth to have been at some period of its long past history a heated mass. The heat subsides. The outside, of course, cools before the interior, and becomes a spherical crust, while the parts underneath are still heated and form a pasty sphere. This in its turn cools. In doing so it contracts. What is the consequence? Some portions of the solid crust fall in toward the centre of the earth.



STRATA FOLDED.

In this process the crust must obviously be crumpled or folded somewhat like the skin of a baked apple, so as to be packed into the diminished space. The diagram will perhaps serve to convey an idea of this.

Two cases may occur: (1) if the strata, when depressed, are in a plastic state, there will be a simple *flexure* or curving at the points, *a a*; (2) if the strata are quite cooled, then there may arise a *fracture* at the same points. The former case may be compared to the bending of a piece of whalebone or a steel spring, the latter to the bending of a piece of wood or iron. It is obvious that the one process will give rounded tops to the mountains, the other will give them jagged peaks and sharp ridges.

7. *Valleys* are depressions through which usually water-courses run. Every mountain range is intersected by valleys, and every mountain-system has valleys separating its parallel ranges. The valleys intersecting ranges are called ***transverse***. Those lying between parallel ranges, and having therefore the same general direction, are called *longitudinal*.

The formation of mountain valleys is due to the upheavals and depressions which have disturbed the surface of the earth in the manner indicated in paragraph 6, previous page. The formation of valleys is really a part of the folding process by which mountains are formed. The action of running water has, of course, widened and deepened them.

BLACK CAÑON, COLORADO RIVER.

Valleys traversing plains and plateaus have been formed by the erosive action of water. Of such valleys the most extraordinary in the world are the cañons of our western rivers.

That of the Colorado is a gorge shut in by almost perpendicular walls of rock. It is from 3,000 to 6,000 feet in depth, and 300 miles long. The cañons are among the most impressive evidences of the age of our earth. Hundreds of thousands of years would be a brief period for performing the work of wearing away the solid rock by running water to the depth of more than a mile.

Transverse valleys render it possible to cross the lofty mountain ranges. Human ingenuity and industry have improved these natural courses of travel, or *passes*, as they are called, and some of them have been made marvels of engineering skill. The Simplon, St. Bernard, and the St. Gothard, crossing the Alps, are among the most noted. The Alpine tunnels have, to a large extent, taken the place of the passes.

8. *Causes and Effects of Relief.*—Few topics connected with Physical Geography have greater interest than the questions, how were the elevations of the earth produced, and, of what use are they in the terrestrial machinery.

CAUSES.—What precisely may have been the causes of the general elevation of the continents, we cannot with certainty tell. On the principle that like effects are due to like causes, we should conclude that similar forces produced the general elevation as those to which we refer the formation of mountains. Whatever may be our conclusion on this point, it is clear that there have been forces at work for untold ages, silently and gently, but steadily raising some portions of the earth's surface, and depressing others.

In many cases it is evident that not only lowlands such as the Mississippi Valley, but even mountain tops, were once at the bottom of the sea. Norway and Sweden, with the Scandinavian mountains, are rising at the rate of 2½ to 5 feet in a century. On one of the mountains of Wales is an ancient sea-beach elevated 1,300 feet above the present shore.

On the other hand many parts of what is now the ocean floor were once dry land. Greenland is gradually sinking.

There is reason to believe that all that part of the Pacific Ocean, embracing an area of several millions of square miles, which so abounds in coral reefs, is gradually subsiding.

EFFECTS.—The *elevations* of the earth's surface, though in one sense insignificant, are properly to be regarded as *important regulators of climate.* Not many hundred feet added to the relief of a country would suffice to alter its physical aspects entirely, converting vineyards into pasture lands, or pasture lands into regions of perpetual snow. Reverse changes would result from a corresponding diminution in the average elevation. [See p. 74.]

Again: *Relief is the great regulator of drainage.* If the surface of the earth had been a dead level, without a hill to embellish the landscape, there would have been no water-courses. The whole land would have been one broad marsh incapable of drainage, and unsuited for human occupation.

TOPICAL ANALYSIS.

II. FORMS OF LAND.

1. **Horizontal Forms.**
   Irregularity of continental outlines. Difference between northern and southern continents. Relation of this difference to commerce.
2. **Vertical Forms.**
   Average elevation of the land. Relative insignificance of the highest elevations.
3. **Forms of Relief.**
   Lowlands. Highlands.
4. **Plains.**
   Extent and varieties of plains. Marine. Alluvial. Relation of plains to civilization.
5. **Plateaus.**
   General character. Elevation. Productiveness.
6. **Mountains.**
   Distribution. Formation. Crumpling and folding process.
7. **Valleys.**
   Transverse. Longitudinal. Formation of valleys. Of western cañons. Mountain passes.
8. **Causes and Effects of Relief.**

Test Questions.—Can you name any region that is lower than the sea-level? What locality contains the highest mountains in the world? Is the Mississippi Valley transverse or longitudinal? The valley of the Amazon? Of the Potomac? Relation of mountain passes to commerce.

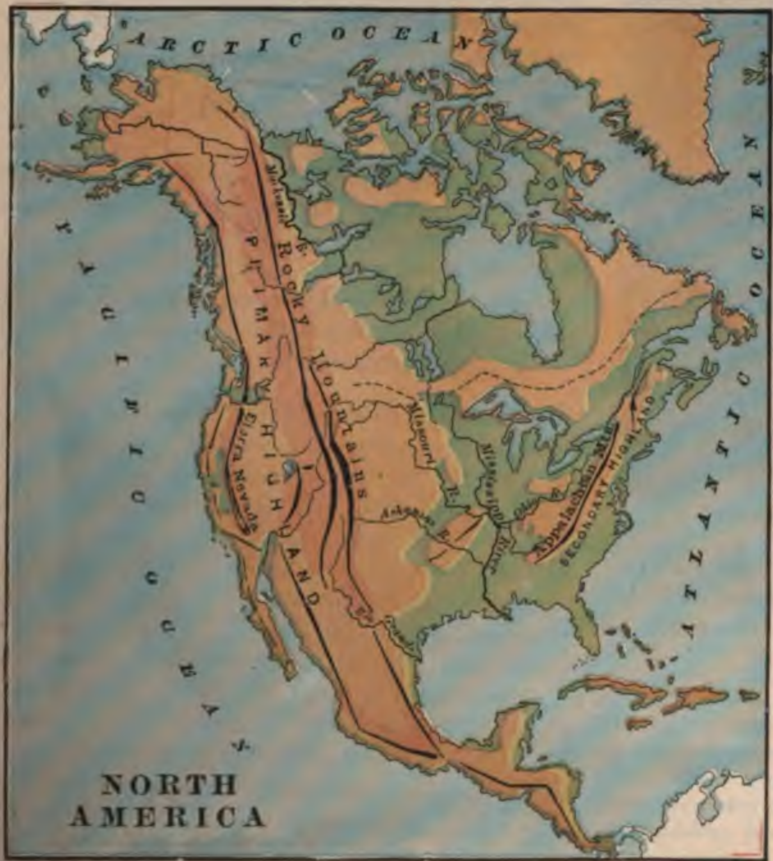
III. RELIEF FORMS OF THE CONTINENTS.

1. General Features of Continental Relief.—There are certain features of relief which belong to all the continents in general. (1) Each continent is bordered by mountains. (2) Each continent is traversed in the direction of its greatest length by a grand mountain-system. The line of direction taken by the principal mountain-system is termed the main or *primary axis* of elevation.

This axial line is not, however, in any case placed centrally, as the word axis might seem to imply, but far to one side of the continent. It thus divides the continent into two unequal slopes. (3) For the most part a subordinate system occurs in each of the continents. This system follows a *secondary axis* of elevation. (4) The *central portions* of each continent are comparatively depressed.

Note.—The relief maps and profile sections accompanying them will be found very useful. Their examination in connection with the text will serve to impress upon the minds of the pupils the conspicuous features of continental relief.

The heavy black lines upon the maps represent, in a general way, the extent and direction of the mountain chains. The elevations and depressions are shown in the profile sections. They are indicated also by the buff and green colors on the maps. The buff, according to the depth of its tint, represents elevations of greater or less altitude. The green indicates lowlands.



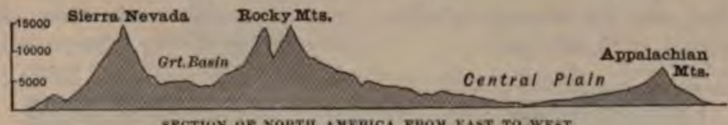
NORTH AMERICA.

1. North America conforms very closely to the general principles of continental relief. It has a primary highland, a secondary highland, and a great central depression.

2. Pacific Highland.—The primary elevation of North America is the vast area known as the Pacific Highland. It consists, in general, of a high plateau from which rise the Rocky Mountains and the parallel Sierra Nevada and Cascade ranges. The plateau varies in breadth from 300 to 600 miles. The general elevation increases toward the south. On the Arctic shores it is 800 feet above the sea; in Mexico it is more than 8,000.

The Rocky Mountain System is composed of several nearly parallel ranges which form the main axis of the continent. It embraces also numerous intersecting cross ranges. The system extends from the Arctic Ocean to the Isthmus of Panama, the Sierra Madre range of Mexico being regarded as the southern prolongation.

From the plateau upon which the mountains stand they do not attain a height of more than 6,000 to 8,000 feet, but when it is remembered that the plateau itself is 5,000 or 6,000 feet high, it will be seen that their actual elevation above the sea-level is as much as 12,000 or 14,000 feet. Their loftiest peaks are about 15,000 feet high.

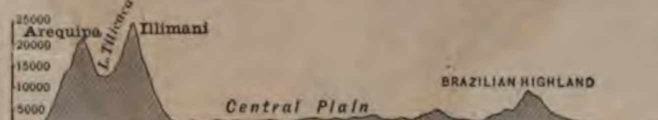


SECTION OF NORTH AMERICA FROM EAST TO WEST.

THE SIERRA NEVADA AND CASCADE MOUNTAINS follow, in general, the line of the Pacific coast. They form the westward wall or buttress of the great plateau. In altitude they resemble the Rocky Mountains. Their loftiest peak is Mount St. Elias, 19,500 feet high.

The low Coast Range stretches along the shores of the Pacific between Cape St. Lucas and Vancouver's Island.

3. The Secondary Highland of the continent comprises the Appalachian mountain-system and the plateau of Labrador. These extend from Labrador nearly to the Gulf of Mexico. The *Appalachian Mountains* in their northern course consist of a number of disconnected groups. To the southward they are composed of several well marked and nearly parallel ranges.



SECTION OF SOUTH AMERICA FROM EAST TO WEST.

The general elevation is not more than about 3,000 feet above the sea, but the loftiest peaks are over 6,000 feet high.

From the Appalachian Mountains the land descends gradually to a low, narrow coast plain known as the "tide water" region.

4. The Central Region between the primary and secondary highlands is called the Great Central Plain. It is a well marked depression extending from the Arctic Ocean to the Gulf of Mexico.

The Height of Land, a narrow ridge crossing it from east to west, having an elevation of from 1,000 to 2,000 feet, divides it into two distinct portions. One slopes to the north and drains off the waters into the Arctic Ocean and Hudson Bay, the other inclines toward the south, and drains into the Gulf of Mexico.

SOUTH AMERICA.

1. The general features of South America are similar to those of North America. The primary elevation of the continent lies along its western border. Secondary highlands are found toward the eastern coast. Central plains lie between the primary and secondary highlands.

2. The Primary Highland of the continent is formed by the Andes, the grandest mountain system of the western hemisphere. It stretches from the Isthmus of Panama all along the western edge of the continent down to Cape Horn, a distance equal to one-sixth the circumference of the earth. The Rocky Mountains of North America may be appropriately regarded as its northern prolongation.

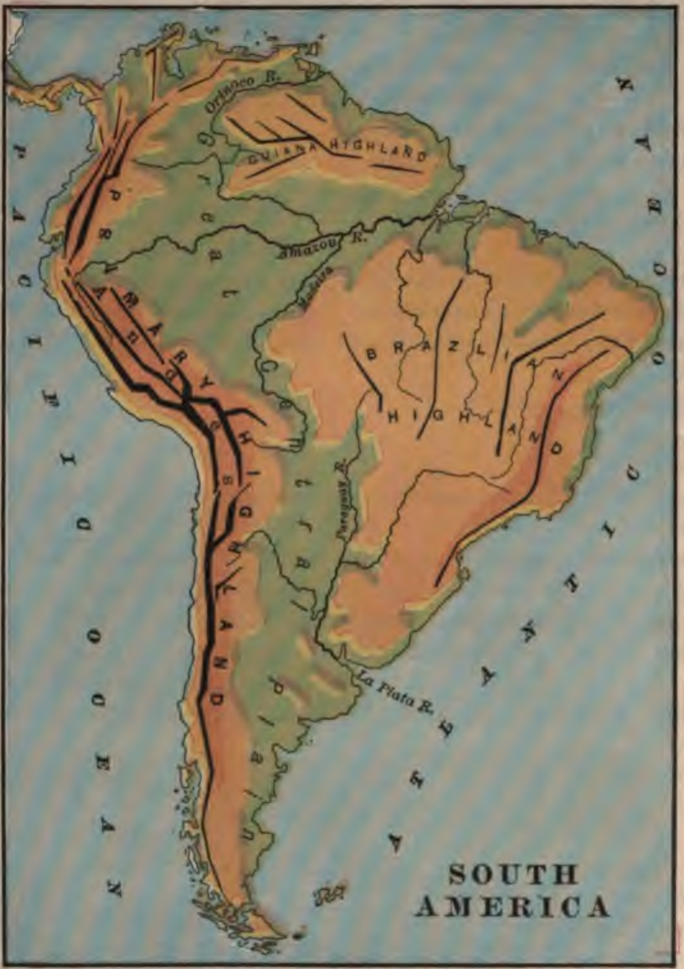
THE ANDES are remarkable for the continuity of their height, for their regularity of form, and for their system of parallel chains. In the southern portion they consist of a single chain; in the central part mainly of two nearly parallel chains; and in the north of three. Eight times these parallel chains gather into mountain knots, and, again separating, enclose valleys and tablelands wonderful in height and extent.

TOP OF THE ANDES.

Of these table-lands the broadest and highest is that of Bolivia.

Passing northward we observe the lofty crest of this imposing system crowned with hundreds of snow-capped peaks, and studded with smoking volcanoes, all the way from the Desert of Atacama to the centre of the United States of Colombia. In the whole of this distance of nearly three thousand miles, there is not a gap or a pass below the height of 11,500 feet. Twenty peaks attain a height of more than 19,000 feet, and the average elevation is estimated by Humboldt at 11,840 feet.

Very important in its bearing upon the physical geography of the continent is the singular proximity of the Andes to the western coast. Their greatest distance from it is about 80 miles.



SOUTH AMERICA

3. *The Secondary Highlands* of South America are those of Brazil and Guiana.

The *Brazilian Highland* is a broad plateau region traversed by nearly parallel ranges of moderate elevation. Their loftiest peaks are from 5,000 to 10,000 feet high.

The *Highland of Guiana* is a plateau supporting several closely-set ridges, the most important of which are the Parime Mountains. Maravaca, the culminating peak, is nearly 10,000 feet high.

4. *The Central Region* of the continent, like that of North America, is a well-marked depression lying between the primary and secondary highlands. It is called the Great Central Plain. It consists of the river-basins of the Orinoco, the Amazon, and the La Plata. These are divided by ridges so low and so narrow that the three together may not unfairly be considered as forming one great basin.

The following curious facts will show how nearly alike their level actually is. The Cassiquiare, which rises between the Amazon and the Orinoco, forks, after running some distance, and sends off one branch to the south to unite with the waters of the Amazon, the other to unite with those of the Orinoco on the north; it thus connects these two river-basins by a water-way that permits the Indians to pass in their canoes from either of the two great rivers into the other.

Furthermore, in the Brazilian province of Matto Grosso there are two springs side by side, and within a few feet of each other. From one the water flows into the Amazon, from the other into the La Plata; and so close are the navigable waters of these rivers to each other, that, with a single portage of a few miles, the voyager, ascending the La Plata from the sea, may return to the ocean again, either through the Amazon or the Orinoco.

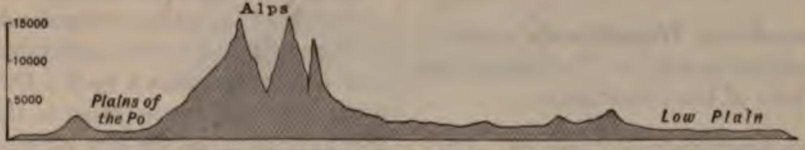
EUROPE.

1. Europe, like North America and South America, has its primary and secondary highlands and its low plain; but the arrangement of these features is different from that which prevails in the New World. Two obvious differences present themselves: (1) the main axis of elevation extends east and west, not like the Andes and Rocky Mountains, north and south; (2) the mountain chains have not the same well-marked parallelism as is shown by those of the New World.

2. *The Primary Highland* of Europe stretches all through the southern portion of the continent, from the Atlantic to the Black Sea, and we may say, regarding the Caucasus as its eastern prolongation, that it reaches the shores of the Caspian.

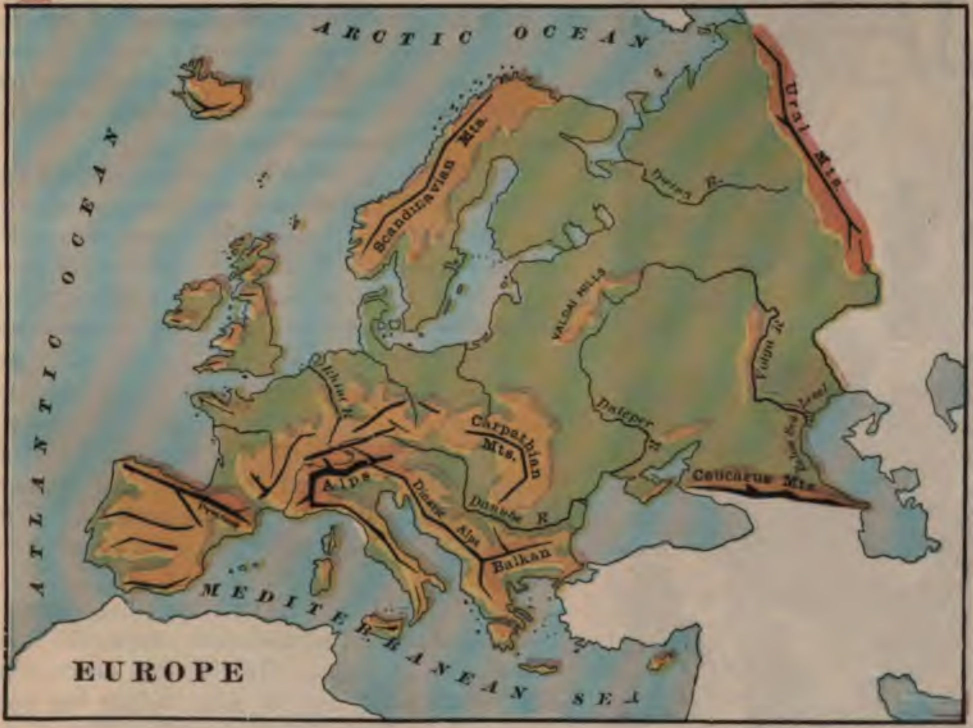
Beginning with the Pyrenees, as its western termination, it culminates in the Alps. Eastward of the Alps it throws out two important branches, the Carpathians to the north, and the Balkans to the south. These, with the Dinaric Alps, enclose the basin of the Danube. In addition to these ranges the Apennines of Italy and the mountains of Greece are included as parts of the primary system.

The Alps are the most celebrated of all the mountain-systems in the world. Their historic and poetical associations; the grandeur and beauty of their varied scenery; the number and extent of their glaciers, and their accessibility to travellers, invest them with an interest unrivalled by the loftiest summits of other lands.



SECTION OF EUROPE FROM NORTH TO SOUTH.

Occupying a central position between France and Germany on the north, and Italy on the south, they can be reached in a few hours from any of the great cities of Europe. Owing to their varied attractions they are visited by so many thousands annually, that they have been called, not inappropriately, "the play-ground of Europe."



"As we climb the Alps," says a distinguished scientific writer, "peak rises behind peak, crest above crest, with infinite variety of outline, and with a wild grandeur which often suggests the tossing and foaming breakers of a stormy ocean. Over all the scene, if the air be calm, there broods a stillness which makes the majesty of the mountains yet more impressive. No hum of bee or twitter of bird is heard so high. No brook or waterfall exists amid those snowy heights. The usual sounds of the lower ground have ceased. Now and then a muttering like distant thunder may be caught, as some loosened mass of snow or ice falls with a crash into the valleys; or the wind brings up from below in fitful gusts the murmur of the streams which wander down the distant valleys."

The highest peaks of the Alpine system are Mont Blanc, 15,784 feet, Monte Rosa, 15,223 feet, and the Matterhorn, 14,780.

The Alps are destitute of active volcanoes.

The *Pyrenees* present a much greater uniformity of arrangement than the Alps. Their average height (8,000 feet) is not greatly inferior to that of the Alps (8,000 to 9,000 feet); but their highest peak, Mount Maladetta, 11,167 feet, is far below the towering masses of Mont Blanc and Monte Rosa. The passes of the Pyrenees, however, are higher and less practicable than those of the Alps.

The *Carpathians* separate the plains of Hungary from the great low plain of the continent. Their greatest elevation is about 9,000 feet.

The *Caucasus* range stretches from the Sea of Azov to the Caspian. Two of its peaks, Mount Elburz, 18,572 feet, and Kasbek, 16,545, surpass in height the loftiest summits of the Alps.

Peninsulas.—High Europe throws out three mountainous projections towards the south: the Iberian or Spanish Peninsula on the west, the Italian in the centre, and the Grecian on the east.

The *Iberian* or *Spanish Peninsula* is a great plateau surmounted by several parallel ranges. The Pyrenees, which are the principal of these, form the dividing line between France and Spain.

In the *Italian Peninsula* we find the Apennines, an important prolongation of the Alpine system. These are more famed for their beauty than for their altitude. The volcanoes of Vesuvius, Etna, and the Lipari Islands, are considered as belonging to this chain.

The *Grecian Peninsula*, like the Italian, boasts of no very elevated ranges. Its mountains are famed less for their height than for their historic and poetic associations. They were the mythic homes of the gods of ancient Greece. The throne of Jupiter rested on Mount Olympus. The Balkans are the most important range. They have an average elevation of about 5,000 feet.

3. The Secondary Highlands comprise the ranges of Scandinavia and the Ural mountains, together with others of less importance.

CLIMBING THE ALPS.

The *Scandinavian* mountains consist, for the most part, of a broad elevated region, intersected by deep and gloomy valleys. Some of these "*fiords*," as they are called, are thousands of feet in depth, and penetrate far into the country. One of them is 100 miles in length.

The *Ural* mountains form a natural boundary between Europe and Asia. They extend southward, 1,200 miles, from the Arctic Ocean nearly to the Caspian Sea.

4. Low Europe consists of a vast plain lying northeast of the primary highland. It is bordered on the northwest by the mountains of Scandinavia, and on the northeast by the Ural range. It extends from the Arctic Ocean to the Black Sea, and westward as far as the Bay of Biscay.

The *Valdai Hills*, near the centre of the plain, mark the highest point of a swell which separates the rivers flowing into the Baltic and White Seas from those which enter the Black and the Caspian.

ASIA.

1. Asia, like Europe, may be divided into two grand sections, High Asia and Low Asia. As in the case of Europe, the highlands lie to the south; the great low region to the north.

2. The Primary Highland of the continent consists of two portions: (1) the various mountain chains which radiate from the central elevated region known as the Plateau of Pamir; and (2), the Plateau of Thibet.

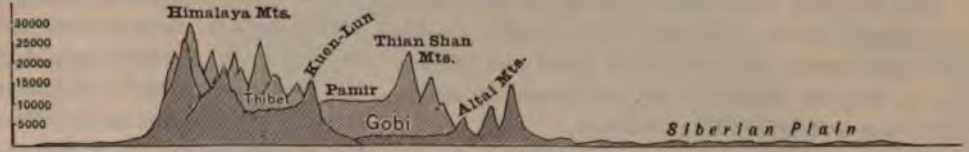
The *Pamir* is called by the Asiatics the "roof of the world." In shape it may be regarded as an irregular square. From three of its corners great chains project. The southeast corner is the starting point of the great ridges of the Himalaya, the Karakorum, and Kuenlun. From the northeastern corner the Thian Shan range takes its origin. From the southwestern starts the line of the Hindoo Koosh.

The *Plateau of Thibet* lies between the Himalayas on the south, and the Kuenlun mountains on the north. It is the *loftiest table-land in the world*, having an extreme elevation of about 15,000 feet.

THE HIMALAYAN RANGE stretches eastward from the Pamir in an unbroken course, for a distance of 1,500 miles. Its breadth varies from 150 to 350 miles, and its mean height has been estimated at 6,000 feet higher than that of the Andes. Over forty of its peaks rise to an altitude of 23,000 feet, and more than 120 reach 20,000 feet. *Mount Everest, with an elevation of* 29,000 *feet, is, so far as known, the highest mountain on the globe.*

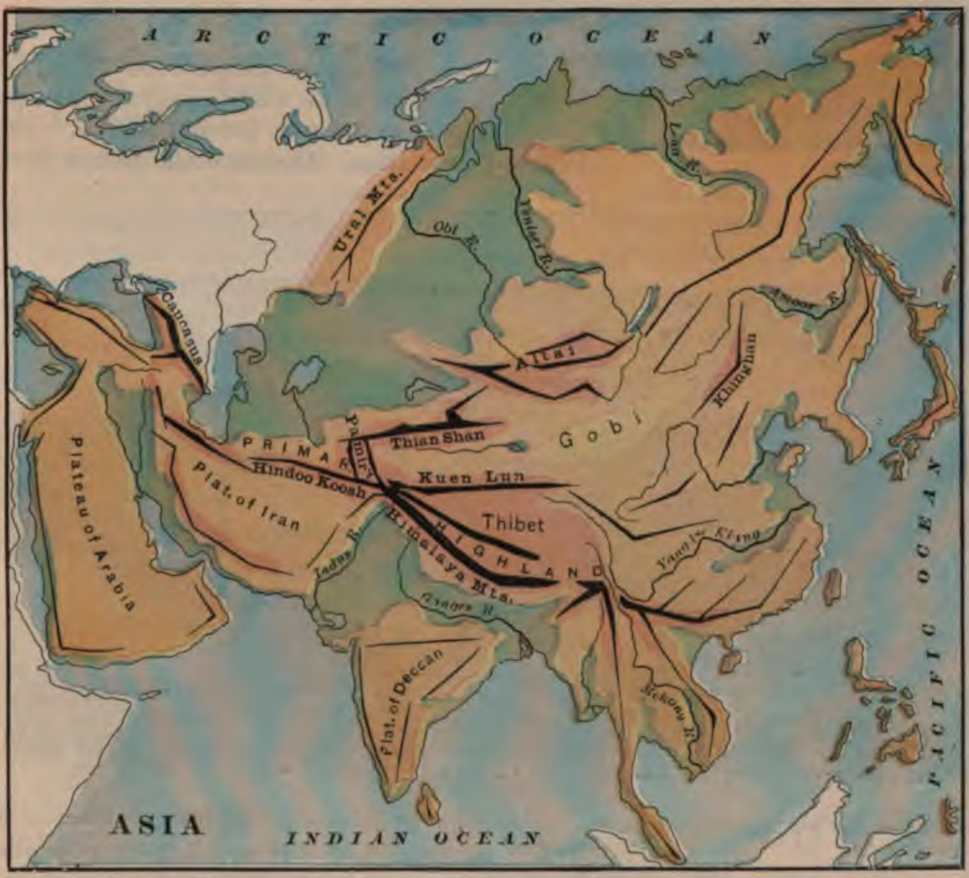
The Himalayas present the grandest possible mountain scenery; deep gorges wrapt in perpetual twilight gloom; frightful precipices; sombre forests of rhododendrons and pine trees; higher up, vast glaciers filling the ravines, and ice and snow covering the ridges which rise one above another to such sublime heights as must ever secure their summits immaculate from the footsteps of man. Everything is colossal; but the Himalayas lack the smiling valleys and sheltered lakes which impart such picturesque charm to the Alps. They possess the grandeur without the amenity, the magnificence without the variety, which mark the less elevated European system.

The *Passes of the Himalayas*, instead of leading through low gaps and over gentle declivities, rise up into the regions of perpetual snow and ice, and are so difficult as to be of little avail for the purposes of commerce between the people on the opposite sides. They are on an average 10,000 feet higher than those of the Alps, and nearly 4,000 feet higher than those of the Andes. We cannot be surprised that India and Siberia are practically farther removed from each other than if they were separated by an ocean, nor even that the opposite slopes of the Himalayas are occupied by men of different races.



SECTION OF ASIA FROM NORTH TO SOUTH.

The *Karakorum* range traverses the plateau of Thibet, and is believed to have a greater average height than even the Himalayas. It contains Dapsang mountain (height, 28,300 feet), believed to be the highest summit next to Mount Everest in the world.



The *Kuenlun* range separates Thibet and Eastern Turkestan, and is prolonged by the Chinese range of the Peling mountains. The *Thian Shan* range forms the northern boundary of the plateau of Eastern Turkestan. Some of its peaks attain the height of 20,000 feet.

The *Hindoo Koosh* extends in broad, massive ranges westward for 400 or 500 miles. A depression then occurs. The range, however, is really continued in the Elburz mountains, which form the northern boundary of Persia.

The general direction of the great mountain chains of the primary highland region is east and west.

3. The Secondary Highlands comprise the Altai mountains and their northern continuations, together with the Great Khingan range, and the ranges of southeastern Asia, and, finally, the subordinate plateaus of the continent.

The *Altai* mountains extend in a northeasterly direction, and terminate in the Yablonoi and Stanovoi ranges. They separate the desert wastes of Mongolia from the plains of Siberia. Some of their peaks are 12,000 feet high.

The *Great Khingan* mountains, with their southern offshoots, form the eastern barrier of the great Desert of Gobi.

PLATEAUS are a prominent feature of the Asiatic continent. A series of them extends from the shores of the Red Sea nearly to the Pacific Ocean. In general they are arid and rainless, sandy, stony, and barren. In the spring the surface is thinly sprinkled here and there with grass and herbs, but in the summer and autumn it is, for the most part, dry and sterile.

The sheltered valleys are, however, in many cases exceedingly fertile. In such valleys there is a settled population, but outside of them the plateau region may be described as the home of roving herdsmen and marauding Bedouin.

North of the Kuenlun mountains are two plateaus, *Eastern Turkestan* and the *Desert of Gobi*. These are shut in on the north by the Thian Shan and Altai mountains. The average elevation of Eastern Turkestan is about 2,000 feet above the sea-level; that of Gobi about 4,000 feet. Entering Gobi from Thibet, we should descend nearly 9,000 feet.

The triangular plateau of the *Deccan* in India rises to the average height of about 3,000 feet. The sides of the triangle are the Eastern Ghauts, the Western Ghauts, and on the north the Vindhya mountains.

The plateau of *Iran* or *Persia*, including large portions of Afghanistan and Beloochistan, is shut in by the Elburz and Hindoo Koosh mountains on the north, by the Zagros chain on the south, and the Suleiman on the east. It rises from 3,000 to 4,000 feet above the sea-level.

The plateau of *Armenia*, with Ararat (about 17,000 feet high) for its culminating point, rises to the westward of Persia.

The plateau of *Asia Minor* lies westward of that of Armenia. It has an average elevation of 2,500 feet. The Taurus ranges bound it on the south.

DESERT of SAHARA

The plateau of *Arabia* forms the southwestern projection of the continent.

4. The Great Lowland of the Asiatic continent lies to the north. It extends from the shores of the Arctic Ocean southward to the base of the Altai mountains and the adjacent ranges, and comprises the Kirghiz Steppes and the Siberian Plain.

It is a part of the almost continuous depression which extends through Europe and Asia, from the North Sea to Bering Strait, a distance of more than 5,000 miles.

The *Kirghiz Steppes* are wide and monotonous tracts, covered in spring with rough grass, desert in summer, and bleak and desolate in winter.

The *Siberian Plain* consists of prairies and piny forests in its southern portions; of swampy tundras on its northern edges.

Inferior in size to the Siberian Plain, but vastly more important for their influence upon the history of the human race, are the plains of China and India. They support nearly one-half the population of the globe.

A remarkable depression is found on this continent. It is occupied by the Dead Sea, the surface of which is 1,300 feet below the level of the ocean. That of the Caspian is 84 feet below.

AFRICA.

1. The Continent of Africa obeys quite closely the general law of continental structure. It has mountain ranges along the coast, while a plateau region of less elevation occupies the interior.

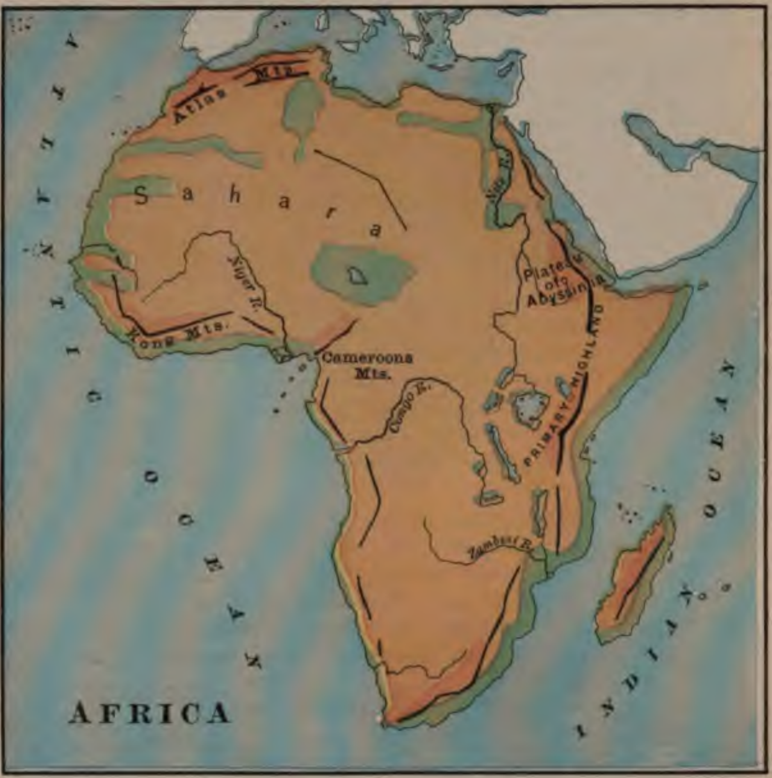
2. The Primary Highland is in the east. It consists of an elevated region which extends all the way from the Isthmus of Suez to the Cape of Good Hope. One important portion of it, the plateau of Abyssinia, attains an elevation of 7,000 to 8,000 feet. The culminating points, however, are the snowy heights of Kenia, Kilima-Njaro and the Ruwenzori Mts. (about 19,000 ft.), near the equator. South of these elevations occur the Livingstone mountains, walling in lake Nyassa; and nearly at the southern extremity of the continent lie the Snow mountains, which be considered as vast terraces ascending from the sea toward the interior.

3. The Secondary Highlands include the ranges which border the northern and western coasts. The Atlas mountains on the north consist of three or four parallel ranges which ascend from the Mediterranean stage by stage, and increase in height to the westward.

The Kong and Cameroons mountains are the principal ranges on the west. The latter are volcanic. They attain at some points the height of 13,000 feet.

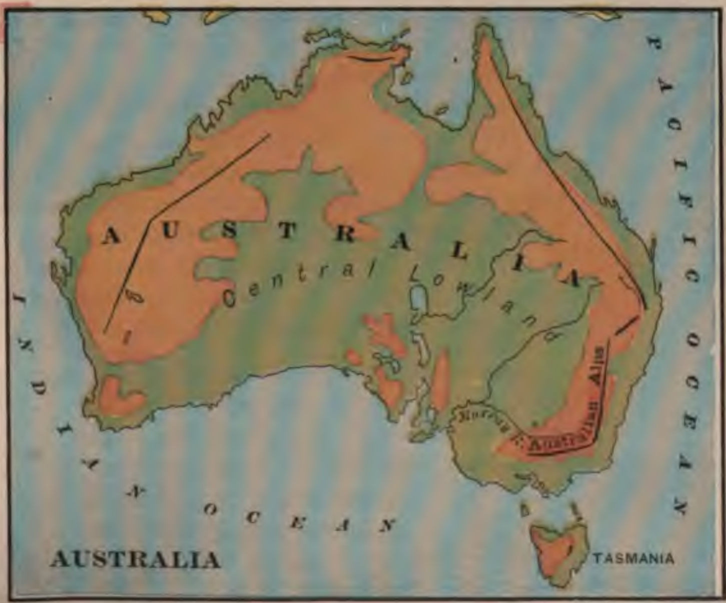
4. The Interior of the continent may be regarded as a vast plateau bordered by the various coast ranges. Low plains are to be found only along the coast.

The plateau region may be divided into two sections: (1) that portion which consists of prairies and fertile river basins; and (2) the arid Sahara.



The SAHARA stretches east and west 3,000 miles, north and south, 1,000, covering an area of 2½ millions of square miles. It is not an absolute level. Its average elevation is about 1,200 feet, but it contains areas which are 4,000 or 5,000 feet in height, and has a mountain range one of whose peaks is nearly 8,000 feet ward of Tunis are found depressions some of which are 100 feet below sea level. They are marshy regions known as chottes (*shots*).

The surface of the desert consists, in some places, of sharp stones, in others of gravel, in others again of shifting sand. This last is driven before the wind, and arranged like long, huge billows of the sea. Here and there are fertile spots called *oases*.



AUSTRALIA.

1. Australia resembles Africa in conforming to the general law of continental relief. It has an elevated border and a depressed interior.

The *Primary Highland* lies along the eastern and southeastern shores. It culminates in the Australian Alps, the loftiest peaks of which are about 7,000 feet high.

The *Secondary Highland*, bordering the western and northwestern edges of the continent, has an average elevation of 2,000 to 3,000 feet.

Of the *Central Lowland* only small portions, such as the basins of the Darling and Murray rivers, are well known. Large areas are believed to be desert. A characteristic feature of the lowland is its inland salt lakes, several of which are more than 100 miles in length.

TOPICAL ANALYSIS.

III. RELIEF FORMS OF THE CONTINENTS.

General Features of Continental Relief.

Location of axial line. Central depressions.

North America.

1. *General Features.*
2. *Pacific Highland.* Description. Rocky mountain system. Sierra Nevada and Cascade mountains. Coast range.
3. *The Secondary Highland.* Description. "Tide-water" region.
4. *Central Region.* Description. Height of land.

South America.

1. *General Features.*
2. *Primary Highland.* Location. The Andes. Remarkable features. Elevation.
3. *Secondary Highlands.* Brazilian Highland. Guiana Highland.
4. *Central Region.* Consists of what ?

Europe.

1. *General Features,* as compared with those of the American continents.
2. *The Primary Highland.* Location. Principal ranges. The Alps. Circumstances which make them celebrated. The Pyrenees. Carpathians. Caucasus range. Peninsulas ; Iberian, Italian and Grecian.
3. *Secondary Highlands.* Scandinavian mountains. Ural.
4. *Low Europe.*

Asia.

1. *General Features.*
2. *The Primary Highland.* Divisions. Plateau of Thibet. Himalayan range. Grandeur of its scenery. Passes. Karakorum. Kuenlun. Thian Shan, and Hindoo Koosh ranges.
3. *Secondary Highlands.* Consist of what ? Plateaus of Asia, extent and barrenness of. Eastern Turkestan. Desert of Gobi. Deccan. Iran. Armenia. Asia Minor. Arabia.
4. *The Great Lowland.* Location. Kirghiz Steppes. The Siberian plain. Plains of China and India. Dead Sea region.

Africa.

1. *Correspondence to the general law.*
2. *Primary Highland.* Location. Extent.
3. *Secondary Highlands,* include what ?
4. *The interior.* Divisions. The Sahara.

Australia.

1. *Conformity to the general law.*
   Primary Highland.
   Secondary Highland.
   Central Lowland.

TEST QUESTIONS.—Considering Europe and Asia as one continent, where would be the central depression ? Do you know anything remarkable about it ?

IV. ISLANDS.

1. Classification.—A portion of the dry land consists of islands. These are divided into two general classes, *continental* and *oceanic* islands.

2. Continental Islands, as the name implies, are situated near the continents, and in earlier periods of the world's history many of them doubtless actually formed parts of the continents. This conclusion is based upon the resemblances that exist between the islands and continents in their rocks and soils, and in their vegetable and animal productions.

From the fact, for example, that in past geological periods the same animals lived in Great Britain as in Europe, geologists are convinced that Great Britain and the adjacent islands were originally connected with the European continent.

Continental islands are usually arranged either in a line parallel to the coast of the continent, or upon a line which may be fairly regarded as a continuation of the continental coast line. The Japanese Islands illustrate well the parallel arrangement ; the West Indies and Sunda Islands are arranged upon lines which may properly be regarded as prolongations of the eastern shores of North America and Asia respectively. [See map, p. 24.]

3. Oceanic Islands are situated in mid-ocean, far away from the continents. They are arranged sometimes in lines, sometimes in groups of irregular shape. They are strikingly unlike the continental islands. These latter are made up of the same rocks as the continents. The oceanic islands are not. They are composed either of volcanic products or of coral. In regard to formation, oceanic islands are, therefore, of two kinds, *volcanic* and *coral.*

4. Volcanic Islands are arranged, as a rule, along the great bands or belts of volcanic activity which traverse the globe.

Most of them are found within the volcanic belts of the Pacific and the Atlantic. [See p. 18.] There are, however, exceptions to this general rule, many volcanic islands being situated quite irregularly. It is curious that the volcanoes upon islands in the Pacific belt are among the most active in the world ; those in the Atlantic belt are either extinct, or are bordering on extinction.

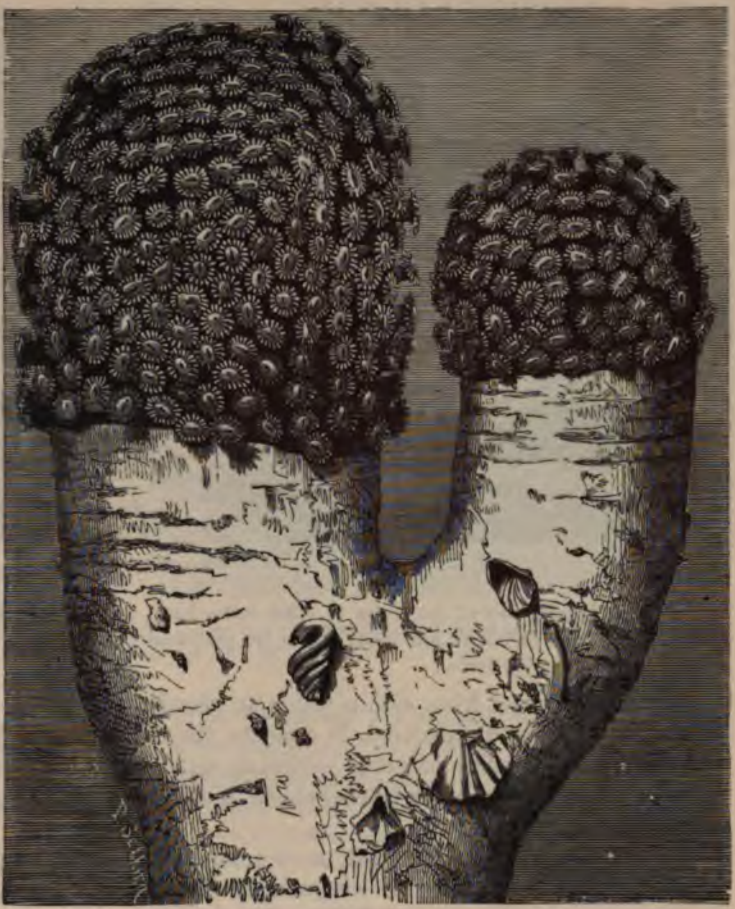
FORMATION.—Volcanic islands are formed by the accumulation of materials thrown out by submarine volcanoes. Sometimes such islands are formed very suddenly, as in the case of Graham Island, in 1831, and of one off the Island of Santorini, in the Mediterranean, in 1866. [See p. 15.]

In elevation above the sea-level, volcanic islands, owing to the method of their formation, are naturally far higher than those of coral origin. Some, like the Sandwich Islands, attain an altitude of many thousand feet.

5. Coral Islands.—Multitudes of islands are mainly composed of coral, and hence are called coral islands. They are formed chiefly by the agency of *coral polyps*, but partly by that of the waves.

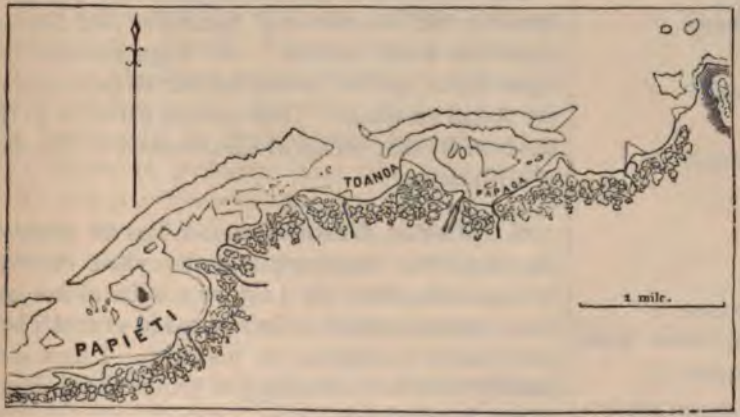
THE CORAL POLYP.—The polyps themselves must first be described, before we can rightly appreciate their work. There are many different species (for the general appearance of which see cut on p. 40), but we need to concern ourselves only about the reef-building polyps. Of these there are various kinds. The cut represents a piece of coral crowned with a colony of tiny laborers.

DESCRIPTION.—The numerous rays which project from the polyps are called tentacles. They are so many little fans which the polyp moves, so as to draw a current of water towards his mouth. The mouth is represented in the cut by a slit in the centre of the rays. The body of each polyp is in a little pocket, or hole, in the substance of the coral. It consists of an outer sack containing an inner sack, this latter being the stomach. In the open space between these two, the bony part of the skeleton of the polyp is formed. It is limestone, and is separated by the polyp from the sea-water which is continuously supplied by the movements of the tentacles.



POLYPS BUILDING CORAL—(natural size).

Then again, although we may consider each polyp as an individual, like a single bee or ant, it is to be observed that the members of such a colony as is shown in the cut are not altogether independent. A common fleshy substance extends from one to the other, and this acts as the individual polyps do. Like them it separates limestone from the sea-water, and makes out of it a sort of common skeleton. With this the skeletons of all the polyps are united so that they form one dense rock-like mass. This substance is known as *coral*.



CORAL REEFS OFF THE NORTH SHORE OF TAHITI.

The life of the individual polyp is brief, but the colony endures for ages. As rapidly as individuals die, others take their place. Young polyps actually shoot like buds out of the substance of the older ones, and, besides this, additional multitudes are hatched from eggs. One vast host of workers then deposits its layer of limestone, and passes out of existence. Another and another succeeds, and thus coral grows and rocky columns rise through the waves to become the supports of coral islands.

WORK OF THE POLYP.—Let us now consider what we may term the life-work of the polyp. It consists in the *building of reefs*.

Coral reefs may be classed as (1) fringing reefs; (2) barrier reefs; (3) atolls.

Fringing reefs are bands of coral rising a few feet above the water, and surrounding islands or skirting the shores of continents. The billows dash themselves into spray on these reefs, but leave the water on the inside as smooth as a mill-pond.

Barrier reefs are the same as fringing reefs, only that they are further removed from the land. Some of them are only a few miles in circumference, others are several hundred.

WHITSUNDAY ISLAND.

The great barrier reef of Australia is 1,200 miles long. The island of New Caledonia and many others are protected from the sea by similar reefs.

An *atoll* is a reef from within which an island, once encircled, has disappeared. It consists, therefore, of a belt or strip of coral enclosing an expanse of water. The water thus enclosed is called a *lagoon.*

Atolls are usually nearly oval or circular, but in many cases they are quite irregular in shape. Sometimes, as in the case of Whitsunday Island, they are complete rings; but most frequently, on the side not exposed to the prevailing winds, there are one or more breaks.

RED CORAL.

The atolls are almost innumerable. There are nearly a hundred of them in the Dangerous Archipelago, which lies to the westward of Tahiti. They are not more than half a mile across, from the sea to the lagoon. In their highest parts they are only a few feet above the water; still they resist the utmost fury of the waves. They are thickly covered with vegetation.

Work of the Waves.—When the polyps have reared their wondrous structure up to the level of low water, they have finished their part in the formation of the coral island. Now follows the work of the waves. They break off portions of the coral growth. They next sweep these portions into a ridge, just as the sand is swept up on the sea-shore. The ridge, heaped up by successive additions of broken coral, finally becomes so high that it overtops the waves, and an island is formed.

The next stage is the appearance of vegetable life. Floating wood lodges among the coral fragments. It decays and forms mould. Seeds, such as cocoanuts, not injured by salt water, are wafted to the new-born islet; others may be carried thither by birds. Under the stimulus of a tropical sun they grow, and in process of time deck the dead coral mass with living green.

The bread-fruit and cocoa-palm are the most important of the forms of plant-life that flourish upon the coral islands. No large animals live upon them, and of course neither metals nor coal are found on them. They are not fitted to be the abode of human beings at all advanced in the scale of civilization.

6. *"Coral Groves" and Coral Seas.*— So singularly transparent is the water enclosed by the atolls, that the ship, as she lies at her anchor, appears rather to be suspended over the bottom than to be resting on the deep. I have seen plainly coral-trees, standing in groves at the depth of one hundred feet.

The coral groves of the ocean floor are decorated like the gardens of the land, the flower-like polyps answering to our pinks and daisies, violets, and lilies. Some of them are of the brightest and softest tints, pink, pearl color, and blue, green, purple and yellow. They strew the bottom, which is of the whitest and purest sand; or hang like leaves and flowers, or cling like mosses and lichens to the branching coral, and lend rare enchantment to the scene. Fishes of many colors, with exquisite grace of movement, dart among the branches. They are as multitudinous as bees over the flower-beds, and, with their polished scales, vie in brilliancy with the feathered tribes of the land. To look down upon such a scene in the great bosom of the ocean is like gazing upon the splendors of fairyland itself.

The full beauty of the coral groves, however, cannot be seen from above. Their admirer must dive to the bottom. Yet not without risk does he venture. The fire coral (Millepora). and the Medusæ swimming amid the treasures of the deep, sting, when touched, like the worst of nettles. Black sea urchins drive their long barbed stings into the flesh of the foot, where they break off and remain, inflicting painful and dangerous wounds. But the worst of all injuries to the skin are inflicted by the coral rocks themselves, owing to their myriads of hard points and sharp jagged edges.

7. Distribution of Coral.—The reef-building polyps are confined to tropical waters which have a temperature of not less than 68° Fahr. The central part of the Pacific Ocean is the scene of their greatest activity. They are also found in many portions of the Indian Ocean, in the Red Sea and the Persian Gulf.

Except among the West Indies, at the Bermudas, and off the coast of Brazil, there are none in the Atlantic.

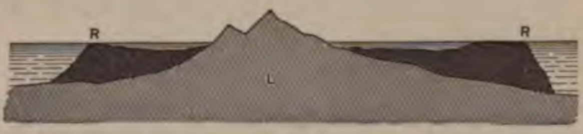
The area within which they are at work is not less than 25 millions of square miles.

8. Origin of Atolls.—Many of the reefs and atolls rise from very great depths; but the polyps are most vigorous in water not deeper than sixty feet; and in water that is more than 150 feet deep they cease to live. The question, therefore, arises, how can the foundations have been laid for certain reefs and atolls, which stand in water not less than a mile and a half deep?

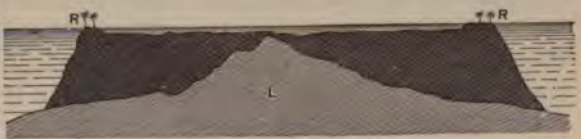
This was a question that long puzzled Physical Geographers. Finally, Darwin suggested an answer. It enables us to understand not alone how atolls in deep water may have originated; but also how atolls in general were formed. It is well known to geologists that the level of the ocean bed is subject to change. It may be upheaved, or, again, it may subside. Darwin conjectured that as fast as the coral reef, ages ago, was being built up toward the surface, it was carried down by the subsidence of the ocean bed.

Explanation.—Let us notice the successive steps of this process. There is reason to believe that in those parts of the ocean where atolls now abound, high mountains once towered. These mountains were islands. The polyps built encircling reefs around them.

But in many cases, as they built up, a gradual subsidence took place, until the island itself disappeared beneath the waves. This subsidence on the one hand, and this building up on the other, may have continued for ages, and to the extent of thousands of feet, so that where the mountain then was, may be now deep waters and low atolls. Thus the mountain-top was replaced by the lagoon, and the encircling reef became the atoll.



(L) Section of mountain rising above water. (R R) Sections of fringing reef resting on slopes.



(L) Section of same mountain submerged: (R R) Sections of same fringing reef become an atoll.

Tahiti affords an illustration of this process. It is a volcanic island with a fringing reef, the foundations of which rest upon the submarine slopes of the island. It exhibits the appearance which must have been presented by existing atolls before the subsidence of the ocean floor had carried down beneath the surface of the sea the mountainous islands formerly enclosed by them.

TOPICAL ANALYSIS

IV. ISLANDS.

1. **Classification.**
2. **Continental Islands.**
   Situation, Character.
3. **Oceanic Islands.**
   How distinguished from continental.
4. **Volcanic Islands.**
   Location. Formation. Elevation.
5. **Coral Islands.**
   How formed. The coral polyp. Description. Work. Coral reefs. Kinds. Atolls. Work of the waves. Origin of vegetation. Characteristic animal and vegetable life. Minerals.
6. **Coral Groves and Coral Seas.**
   Clearness of. Beauty of.
7. **Distribution of Coral.**
8. **Origin of Atolls.**
   Difficulty connected with. Depth at which the coral polyp can work. Darwin's theory. Illustration in Tahiti.

Test Questions.—Would you consider a coral island a desirable place of residence? Why?

TOPICAL ANALYSIS FOR REVIEW.

- **Arrangement of Land Masses.**
  - Relations of air, water and land to each other.
  - Extent and distribution of the land, and shape of the continents.
  - Northern and Southern Hemispheres compared as to extent. As to progress.
  - Land and Water Hemispheres.
- **Forms of Land**
  - Horizontal Forms.
  - Vertical Forms
    - Lowlands. Plains. Various kinds.
    - Highlands.
      - Plateaus.
      - Mountains. Formation of.
      - Valleys. Kinds. How formed.
      - Causes and effects of relief.
- **Relief Forms of the Continents.**
  - General features of continental relief.
  - North America.
  - South America. Resemblance to North America.
  - Europe, general description. Alps. Peninsulas of High Europe.
  - Asia.
  - Africa. The Sahara.
  - Australia.
- **Islands.**
  - Continental.
  - Oceanic
    - Volcanic.
    - Coral.
      - Coral Polyp.
      - Coral Reefs. Classes of.
      - Development of the reef into an island.
      - Distribution of Coral.
      - Origin of Atolls.

PART III.

THE WATER.

I. PROPERTIES OF WATER.

1. Composition.—Turning from the land we come now to the consideration of the water. Its offices are of the highest interest and importance.

Pure water is composed of two gases, hydrogen and oxygen, united in the proportion of two volumes of hydrogen to one of oxygen.

2. Physical Properties of Water.—The properties of water that specially interest the Physical Geographer are the following:

(1) water changes its forms with remarkable readiness;

(2) it expands when passing into the solid state;

(3) it has extraordinary capacity for heat;

(4) it has great solvent power.

Forms of Water.—The three forms of water are the liquid, solid, and gaseous. Changes of temperature that are of common occurrence cause it to pass from one to another of these.

Now it becomes a solid. Falling gently as snow, it muffles up the young plants as with a mantle, screening them from the biting winds of winter; as ice, it covers the surface of the lakes and the rivers, and protects the denizens of the water, as snow does the insects and tender plants of the land.

Now it becomes a gas, and carries off water from the sea to supply the springs among the mountains that give drink to man and beast; or, mantling the earth with an invisible screen, prevents the too rapid escape of its warmth at one time; or, assuming the form of clouds in the sky, shields it from the too great heat of the sun at another.

Having fulfilled these duties, it turns again into beautiful, dancing, laughing water. Enduring as the mountains, it is one of the few visible things on earth upon which time, since the world began, has wrought no marring change. Friction abrades it not, nor have all the keels that have ploughed the ocean wasted so much as one single drop of it. There it is, pure and bright, just as it came from the hands of its Maker; its power is unimpaired and always fresh; it is ever busy and never weary.

Expansion of Water.—Water expands when passing from the liquid state to the solid. This is probably due to the fact that its particles, when crystallized, require more space than before. When cooled, it follows the general law, and contracts until it reaches the temperature of 39.2° Fahr. Below this it disobeys the general law, and expands till it reaches 32° Fahr., its freezing point. Then suddenly it hardens into ice, and attains its maximum expansion.

Because ice is more expanded than water, it is lighter than water, and, as we all know, it floats. The law by which ice floats is one of the beautiful and benign provisions of nature. Were ice heavier than water, it would sink as fast as it was formed, and our river-channels and shallow lakes would be filled with solid ice from the bottom to the top.

Expansive Force.—Another important consequence of the expansion of *water when freezing* is that it *exerts a force that is practically irresistible.* It sunders the solid rock from the foundations of the mountains, and crumbles it into fragments.

One of the most interesting effects of the force exerted by freezing water occurred in Norway in 1717. The snow covering a rocky region had rapidly thawed, and filled the crevices of an enormous mass of rock with water. Suddenly the weather changed. The water enclosed in the crevices of the rock was frozen. Expansion occurred, and a mass of rock was rent away and precipitated into the neighboring fiord. The waters of this being suddenly driven from their channel engulfed a household, and submerged the adjoining fields.

EFFECTS OF EXPANSION PRODUCED BY THE FREEZING OF WATER.

Two bombs having been filled with water, and the fusee holes firmly closed with an iron stopper, were exposed to intense cold; on freezing, the stopper of one was projected to a distance of more than 150 yards, while the other bomb was split open and a sheet of ice was forced through the crack.

Capacity for Heat.—*Water, of all known substances, has the greatest capacity for heat.* The heat of bodies exists in two forms; as sensible heat, or that which you can feel, and insensible, or that which you cannot feel. The latter is commonly called *latent*, or hidden heat.

In the process of evaporation a certain quantity of sensible heat is absorbed and rendered latent; in the opposite process of condensation a certain amount of latent heat is released and made sensible.

The power possessed by a body of storing away heat, and rendering it latent or unfelt, is called its "capacity for heat" or its "specific heat."

Explanation.—Suppose you take a cubic foot of ice at 27°, for instance; put it into a vessel and set it over a steady lamp which affords sufficient heat to raise the temperature of the ice 1° a minute. At the end of five minutes the ice would be at 32°. It will now begin to melt, but the heat, instead of warming the ice or the water, only melts the ice. At the end of 143 minutes all the ice will be melted, but the temperature of the water will still be 32°, and no more. Now what has become of all the heat received from the lamp during these 143 minutes? It has gone to convert the solid into a fluid, and has been rendered *latent*; that is, it has been stowed away and concealed in the water.

Now let the lamp burn, as before, with sufficient intensity to raise the temperature of the water 1° a minute. In 180 minutes the temperature will be raised from 32° to 212°, which is the boiling point; and the water will feel hot. Its heat is sensible heat. The boiling water, however, now ceases to become hotter, but if you let it stay over the lamp, you will find that, at the end of 966 minutes more, it will have boiled away into vapor. Now the vapor thus produced has identically the same temperature as the water, viz., 212°, so that 966° of heat will have become *latent* in it.

Evaporation exerts a cooling influence.—From the above it is evident that ice or water becoming vapor, absorbs heat, and renders it "latent" or hidden.

Condensation of water, on the other hand, *exerts a warming influence.* You must have frequently noticed, how, as a general rule, the intense cold is mitigated just before a snow-storm. This is due to the condensation of vapor into water, and the freezing of that water into snow.

It has been computed that from every cubic foot of vapor condensed, and frozen into snow, heat enough is set free to raise more than 100,000 cubic feet of air from the temperature of melting ice to summer heat.

Nature makes great use of these counter-properties, the evaporation and condensation of water. She bottles away the heat of the torrid zone in little vesicles of vapor, thus cooling the atmosphere. She then delivers these vesicles to the winds to be by them transported to other regions. There they are condensed into rain, and their heat set free to warm the air and modify the climate. [See p. 86.]

The Solvent Power of water is another property of great importance. The forms of plant and animal life are largely built up of materials which enter them in solution. Water acts as a vehicle for conveying these materials into the living system. It is essential therefore to the maintenance of life.

3. *Circulation of Water.*—The readiness with which water changes its form and passes from the liquid state to that of vapor, and from the vaporous to the liquid state again, is the means whereby a constant circulation is carried on from the sea to the land, and from the land to the sea again.

Let us trace its course. Incessantly the waters of the sea are converted by the sun's heat into invisible vapor. This passes into the air, and the winds transport it to the land. Condensed, it falls as rain or snow. It fills the springs and replenishes the rivers; it waters the thirsty lands. Portions of it find their way back to their home in the sea, through the river channels; others, evaporated, rise on the wings of the wind, and again, being cooled, descend as rain or snow.

And thus *all the water of the globe comes out of the sea, as from a reservoir, and it all finds its way back there again.*

TOPICAL ANALYSIS.

I. PROPERTIES OF WATER.

1. Composition.
2. Physical Properties.
   Forms of water. Cause of changes of forms. Uses in the solid form. In the gaseous form. Indestructible nature of water.

Expansion in freezing. Important result.
Capacity for heat. Heat rendered latent in melting.
In evaporation.
Effect of evaporation and condensation of water on temperature and climate.
Solvent power.

3. Circulation of Water.

The great reservoir.

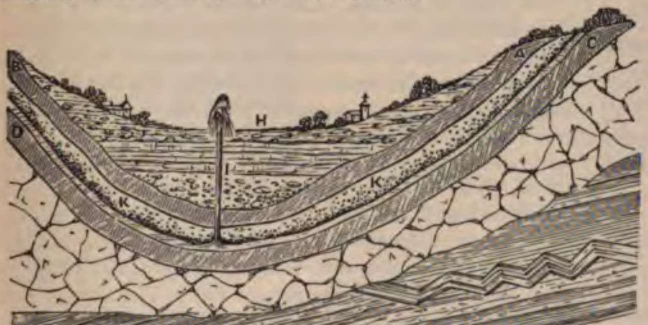
Test Questions.—Name some forms of water remarkable for their beauty. At what temperature is water heaviest? In the circulation of water between land and sea what force carries the water down to the sea? What force carries it back to the land?

II. WATERS OF THE LAND.

1. Springs.—A portion of the rain which falls upon the land flows off to the sea through brooks and rivers. The larger part of it, however, does not flow off, but accumulates in swamps and lakes, or enters the ground. The latter portion, sinking into the earth under the influence of gravity, finally encounters layers of rock which it cannot penetrate. It then follows the incline of these layers, and flows for a greater or less distance, until it reaches a point where the land is depressed. Here it finds egress as a *surface spring*. If the area through which such water percolates be large, and if the slope along which it flows be gentle, then the spring will be perennial or unfailing.

The depth to which percolating water descends is surprising. From a deep well sunk in a certain district of France, pieces of leaves were thrown up by the first gush of water from a depth of about 400 feet. These leaves were comparatively fresh. They were ascertained to have come from a distance of about 150 miles from the spring. A similar phenomenon has been observed in other places.

From the percolation of water through the earth arises one of the greatest difficulties in mining operations. Before the invention of steam-pumps many coal pits in England had to be abandoned owing to the fact that, in the expressive language of the miners, they were *drowned*.



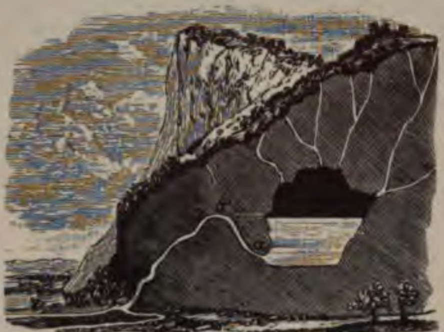
ARTESIAN WELL.

Action of Artesian Wells.—The action of "Artesian wells," so called from *Artois* in France, where they were first used, very clearly illustrates that of natural springs.

Let us suppose that AB and CD, in the illustration, are layers of rock impervious to water, and that at a distance of 500 miles or more from a desert or region ill supplied with water, they crop out upon the surface. Dipping down, however, they are perhaps 1,000 feet below the surface at the point H. Between them is KK, a layer of gravel through which rain water can percolate, but from which it cannot escape, being confined by AB and CD. Trickling down through KK the water accumulates. The tube of an Artesian well, I, sunk through AB, enables it to rise to the height of its distant source.

When the source of supply is very much higher than the surface where the well is sunk, the water shoots upward with considerable force. The jet from such a spring near St. Etienne, in France, rises to a height of about 25 feet.

The French colonists in Algeria have sunk a number of Artesian wells on the margin of the Great Desert of Sahara, and thus supplied themselves with an abundance of water.



INTERMITTENT SPRING.

Intermittent Springs.—The springs which have excited the greatest curiosity are those which, from their alternate subsidence and flow, are called *intermittent*. The cause of this peculiarity is illustrated in the accompanying cut, and will be readily understood by any one who has seen a siphon used.

The passage from the reservoir to the surface of the ground is curved like a siphon and acts in the same manner. Water percolates through the fissures in the rock and accumulates in the reservoir. As soon as it rises above the level of the bend of the siphon, *b*, it begins to flow, and does not cease till it has fallen below the mouth of the passage at *a*. Thus the reservoir alternately fills and discharges itself.

Thermal or Hot Springs and Geysers have been already discussed. [See p. 14.] It remains to be said that the waters of such springs may be ejected in two ways: (1) in the manner above indicated, the water seeking the level of its source; or (2) by the force of steam, or gases superheated by the internal heat of the earth.

Mineral Springs abound in many parts of the world, chiefly in mountainous and volcanic regions. Their waters are charged with various substances. Iron, salt, sulphur, and carbonic acid are the most common ingredients.

2. Rivers.—Rivers receive their supply of water from springs, or melting snow-fields and glaciers. From various springs in one vicinity little streamlets pour their contributions. Influenced by gravity these seek the lowest level. They unite and form a *river*. Again, just as the streamlets issuing from a number of springs make a river, so a number of rivers, all seeking the channel of greatest depression, blend together and make one mighty water-course. Such a water-course, with its tributary streams, is called a *river-system*.

WATER DOING ITS WORK—RAVINE OF OCOBAMBA.

Not unfrequently on the way to the sea a river passes by a very sudden descent from a higher to a lower level. This gives rise to *cataracts*. According to the violence of the descent they are classed as *rapids* or *waterfalls*. When the descent is very abrupt, but still not perpendicular, the term rapids is properly employed. The cataracts of the Nile and the rapids of the St. Lawrence are noted illustrations.

The term waterfall is used when the water drops perpendicularly. The loftiest waterfalls are those of the Yosemite in California, 2,500 feet, and the Keelfoss in Norway, 2,000 feet high.

The grandest of all waterfalls are those of Niagara. Here the water discharged by four of the Great Lakes of North America plunges in a single leap of 160 feet from the terrace of Lake Erie to the lower level of Ontario.

Offices of Rivers.—Rivers, viewed as parts of the terrestrial machinery, have two main offices: (1) *they bring about vast changes in the surface of the earth;* (2) *they are channels by which the drainage of the land is accomplished.*

3. How Rivers Change the Surface of the Earth.—The process by which rivers bring about changes in the surface of the earth has three stages: *erosion; transportation; deposit.*

Erosion means the eating away of the solid materials which form the channel of a river. It is brought about: (1), by the solvent power of water; and (2), by its mechanical force when in motion. These two combined wear away the more soluble and soft clays and rocks with ease; but even the hardest cannot withstand their action.

If the soluble particles of a rock are dissolved by water, the surface of the rock becomes disintegrated, and crumbles. Now, when a stream incessantly runs over such a constantly dissolving and disintegrating rock, it is clear that erosion will make rapid progress. The rock will be worn away.

The fragments thus removed are whirled continuously against the water, against one another, and against the sides and bottom of the channel. And thus, as the river rolls on, the particles eroded become smaller and smaller. In the upper course of the river they may be of considerable size. In the lower course they are reduced to sand and silt.

Example.—The erosive action of rivers is most impressively illustrated by the excavation of rocky gorges. That of the Niagara and the cañons of our western rivers are perhaps the most striking examples that can be offered.

The Falls of Niagara, it is evident, were at one period about seven miles lower down the stream than they now are. The vast volume of water that passes over the falls erodes the edge of the cliff over which it pours. Falling from the height of about 160 feet upon the rocks below, it wears them away; and thus erosion occurs both above and below.

It was computed by Lyell that the rate at which the falls eat their way up the gorge was about one foot a year, and that therefore it had taken them about 35,000 years to pass backward from Queenstown to their present point. At the same rate they would work their way back to Lake Erie in about 30,000 years from the present time. The average rate of recession is now, however, about 2¼ feet per annum, which would reduce the computation to about 15,000 years.

Transportation.—The finer particles of eroded matter are carried along by the river in suspension, that is, simply mixed with the water. The coarser portions are rolled onward by the current. This twofold action constitutes *transportation*.

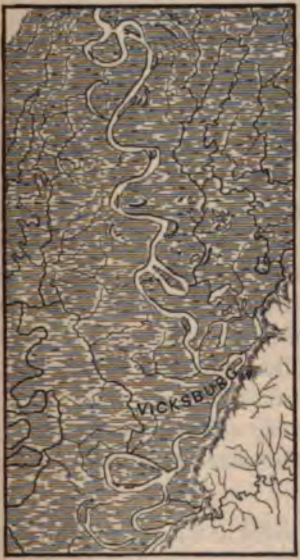
A river will transport eroded matter to a greater or less distance, and in greater or less quantity, in proportion to the velocity and volume of its current. Water moving half a mile an hour will carry along ordinary sand. If the velocity be increased to three-quarters of a mile, it will roll fine gravel, while a current having a speed of three miles an hour, can sweep along pieces of stone as large as eggs. In floods masses of rock as large as a house have been moved.

As to the quantity of matter transported, it is estimated that of visible sediment the Rhone carries into the Mediterranean more than 600,000,000 tons annually, and of salts invisibly dissolved, more than 8,000,000 tons. The amount of silt carried into the Gulf of Mexico by the Mississippi in one year, would make a column one mile square and 241 feet high.

The removal of this matter from the surface of the valley reduces its average level one foot in 6,000 years. Could the same rate of denudation be kept up continually over the entire surface of North America, it would reduce the continent, which has an elevation of about 750 feet, to the level of the sea in half a million years.

Deposit.—The materials borne or rolled along by rivers are deposited at various points in the channel. The finer portions called silt, familiar to us as muddy slime, are carried down as far as the mouth of the river. Farther up the stream sandy particles come to rest; still higher, gravel is deposited; and finally, in the upper course of the river we find stones of greater or less size.

It is obvious that deposit will depend very largely upon the slope of the river-bed and the rapidity of the current. Anything that checks the latter favors deposit.



SINUOSITIES OF THE MISSISSIPPI.

Results of Deposit.—The main results of deposit are changes in river-courses; and the formation of bars and deltas.

Changes in river-courses are frequent effects of deposit. They occur especially in rivers that flow through alluvial lands. Very often the course of such streams is marked by what are called *sinuosities*, or sharp curves resembling the letter S. The lower Mississippi presents a striking illustration of this. [See diagram.] In some cases portions of the land are carried from one side of the river to the other, giving rise to the important question to whom does the land so transferred belong.

Sometimes, as when a river is unusually high, it may make for itself a straight course instead of following its old curves. The impetus of the swollen waters forces them through the soft clay banks. The portion of the old channel that is abandoned is closed by silt at each end, and becomes a lake, crescentic in shape, and commonly called a "cut-off."

Bars.—But by far the most important cases of deposition are those which occur at the mouths of rivers. Here the current of the stream is checked by the mass of the ocean waters, or by the incoming tide. Along the line of meeting, it is clear that there will be comparatively little movement, and in consequence there will be, in the case of large rivers, vast deposits of sediment. In this way *bars* at the entrance of harbors are formed.

The Mississippi, and all the rivers of the United States that flow directly into the Atlantic Ocean, have bars.

So great is the amount of solid matter brought down by the Mississippi that a bar no less than two and a quarter miles in breadth was formed off one of its outlets called the South Pass. Fleets of vessels more than fifty in number might sometimes be seen, detained on the bar for weeks, waiting for a chance to go to sea, or enter the Pass. The operation of towing a ship into the deep waters of the Gulf occupied days, and in some cases weeks.

In 1875 Captain Eads, by the authority of Congress, constructed *jetties* or long walls, which narrowed and confined the current, and thus gave it greater velocity, and, of course, greater power to scour out the channel and carry off the sediment into deep water. A similar project has been proposed for keeping the mouth of the Danube free from obstructions.

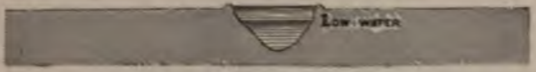
Deltas.—Then again, when the river waters encounter the waters of the sea, the check to their velocity will extend some distance up the stream. Hence deposits are likely to occur near the mouths, and some distance above the mouths, of all silt-bearing rivers. In this way are formed in the course of ages what are termed the *deltas* of rivers.

The Mississippi, the Nile, the Ganges, the Orinoco, the Danube, the Volga, and many other rivers which flow into inland seas or gulfs protected from the sweep of the tides and ocean currents, are famous for their deltas.

But where there is a very strong littoral current, it sweeps off the sediment as fast as it enters the sea, and there is no delta formed. This is the case with the Amazon, the Rio de la Plata, and with all the American rivers that empty into the Pacific Ocean.

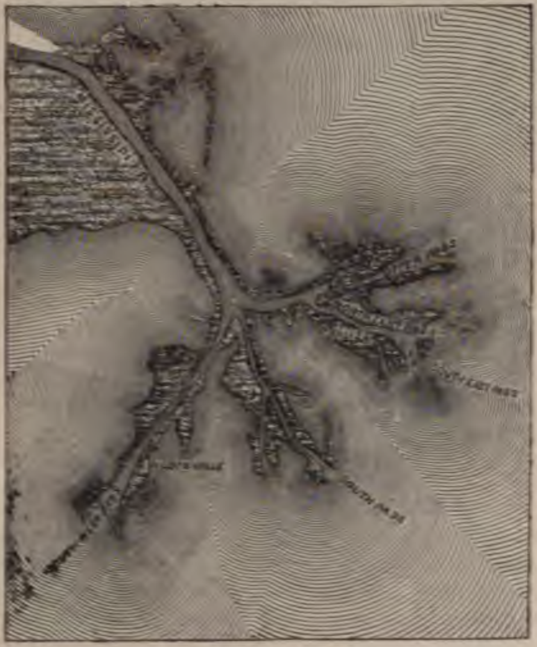
The area of deltas is often very large. That of the Mississippi is about 12,000 square miles. One third of it is still in process of formation, being as yet only a sea marsh.

Branching of Rivers in Deltas.—Not alone is sediment deposited upon the bed of rivers, but also upon their banks.



SECTION OF THE MISSISSIPPI.

This has the effect of raising the banks above the general level of the neighboring country. In some portions of their course both the Mississippi and the Po are above the adjacent fields. The land, therefore, slopes from the river on either side, and one goes *up* to it instead of *down* to it.



DELTA OF MISSISSIPPI.

Now if we bear this in mind, and remember, also, that the natural bank of the river is only a mound of sediment, we shall see how readily, in case of flood, the river may divide into branches and make for itself new outlets. This is to be observed in all delta regions. It is admirably shown in the case of the Mississippi delta in the accompanying illustration.

This branching of rivers in passing through their deltas serves to explain why many rivers, such as the Nile, the Mississippi, the Ganges and others, have more than one outlet.

4. Relation of Rivers to Ocean Life.—When the rivers have discharged their waters into the sea, they have not yet finished their task. Sea-shells and coral-rocks are formed chiefly of the limestone which is dissolved and gathered by the rains and running waters from the mountains, plains and valleys.

Of materials thus collected and brought from Upper Egypt by the Nile, and from the mountains of Asia by the great rivers of India and China, or from the peaks of the Andes by the Amazon—of such materials the great whale and all the fish of the sea form their bones, the pearl oysters make their jewels, the sea-conch its shell, and the coral polyps their evergreen islands.

Water is thus seen to be one of the most wonderful and benign agents in the terrestrial economy. It is as marvellous in its properties, in its adaptations, and in the perpetual development of the most beautiful phenomena, as is the fire on the hearth. It not only performs the offices that are familiar to us all, and which have almost ceased to be observed, or, when observed, have ceased to surprise us, but, ever in a thousand unfamiliar and hidden ways, it is fulfilling the beneficent will of Him who created it.

5. Lakes.—The formation of lake-basins may be ascribed to various causes. Of these the following is, perhaps, the most frequent. When the surface of the earth was crumpled as described on page 28, depressions of greater or less depth were necessarily formed. Some of them, receiving the rainfall drained from neighboring slopes, became the basins of lakes.

FRESH-WATER LAKES.—In the case of lakes situated in cool or damp regions precipitation is in excess of evaporation, or, in other words, the amount of rain falling in the vicinity of such lakes, and carried into them by streams, is greater than the amount of water taken up from the surface by evaporation. They gain more than they lose.

Clearly, therefore, there will come a time when an overflow must occur. The waters that no longer can be contained by the lake-basin, will break through the rim at some weak point, and form for themselves a channel to the sea. In doing this they will sometimes cut pathways through the densest rock, or burst through the barriers of the everlasting hills. Hence rapids and waterfalls, water-gaps, gorges and cañons.

SALT LAKES.—In the case of lakes situated in regions of great warmth and dryness, the amount of water evaporated is sometimes equal to that which is supplied, and sometimes greater. As fast as the water is poured in by the rivers it is carried away in the form of vapor and clouds. Such lakes are never filled to overflowing, and, consequently, have no outlets.

The water of lakes having no outlets is commonly salt. The water of lakes having outlets to the sea is fresh.

Explanation.—Rivers carry into lakes, in solution, many saline materials, of which one of the most abundant is chloride of sodium (common salt). This is present in ordinary river water, although it cannot be tasted; but if a large quantity of such water were evaporated, a small amount of salt

YELLOWSTONE LAKE.

would be left behind. Thus it is clear that if a lake have an outlet, not only is its superfluous water removed, but the salts dissolved in such water are also taken out.

On the other hand, if a lake have no outlet, then, while the water brought in is removed by evaporation, the salt introduced remains behind. Thus lakes having no outlet may be compared to the evaporating vats or troughs in which, as at many points on the shores of the Mediterranean Sea, water is boiled, or evaporated by solar heat in the manufacture of salt. The water passes off, the salt remains. Hence, year after year, salt lakes become salter.

Conspicuous examples of salt lakes are the Great Salt Lake and the Dead Sea. Both of these are heavily charged with saline ingredients. The water of the Dead Sea is about one-fifth heavier than that of the ocean, and sustains the human body, so that it cannot sink in it. From its great salinity the Dead Sea is often called the Sea of Salt. But the Jordan, which supplies it, is of course fresh.

The Dead Sea is situated in a depression remarkable for its intense heat, and the region in which the Great Salt Lake lies is very remarkable for the dryness of its atmosphere. In the case of both these lakes, therefore, evaporation proceeds at an enormous rate.

INLAND SEAS.—Some inland bodies of salt water, however, have evidently been at one time parts of the ocean. These are properly designated inland seas. The most remarkable of them are the Caspian and Aral.

When the Arctic Ocean extended, as geologists believe it did, southward as far as the mountains of Persia, these two seas and many neighboring bodies of salt water were included within its limits.

Seals abound in the Caspian, and sturgeons, herrings and other sea-fish in both the lakes.

Like other salt lakes these inland seas have no outlet. The Volga, the largest river in Europe, and the Ural pour volumes of water into the Caspian, yet its level does not rise. The Sea of Aral receives the Oxus and the Jaxartes, yet its level seems actually to be lower than formerly.

Many small salt lakes entirely evaporate during the summer, and leave their beds covered with saline incrustations. From the dry bed of Lake Elton, in the Caspian region, 100,000 tons of salt are annually gathered.

6. Offices of Lakes.—Lakes are reservoirs for the rivers. They hold the waters back in time of flood, and thus help to maintain a uniform height of water in the rivers. The Arve, an affluent of the Rhone, is the chief cause of the serious inundations which occur in the Rhone Valley. It sometimes pours twenty times its ordinary volume of water into the Rhone. To prevent the floods, it has been proposed to turn the course of the Arve, and make it discharge into the Lake of Geneva.

The inundations of the lower Mississippi are mainly due to the floods of its tributaries, no intervening lakes holding back the surplus waters.

Lakes again are sources from which supplies of vapor are obtained, to be gathered into clouds, and in the form of dew or rain to water the land.

7. Geographical Distribution of Lakes.—In North America are found the vast bodies of fresh water which are called the "Great Lakes." The northern part of the Great Central Plain of the continent abounds in lakes, of greater or less magnitude. In the Basin between the Rocky Mountains and the Sierra Nevada there is a region of saline lakes.

In Europe, the great lake region lies in Northern Russia and Scandinavia. Ladoga and Onega, Wener and Wetter are the largest lakes of the continent. Those of the Alps, Como, Maggiore, Geneva and others are comparatively small, but famed for their beauty.

Asia is noted for the size and number of its salt lakes. The Caspian, Aral and Dead seas are examples. Of fresh water lakes Asia has few. Lake Baikal, however, 400 miles in length, may be compared with our own Lake Superior.

Africa rivals North America in the magnitude of her great lakes. Victoria and Albert Nyanza, Tanganyika and Nyassa are the largest.

South America has two lakes of importance, Titicaca and Maracaybo. Australia is noted for its salt lakes. Eyre, Torrens, and Gairdner each exceed 100 miles in length.

TOPICAL ANALYSIS.

II. WATERS OF THE LAND.

- **1. Springs.**
  - How caused. Artesian wells.
  - Intermittent springs. How caused.
  - Hot springs and Geysers. Forces by which the water is ejected. Mineral springs. Common ingredients.
- **2. Rivers.**
  - How formed. River-systems. Cataracts. Rapids. Waterfalls. Noted falls.
  - Offices of rivers.
- **3. How Rivers change the surface of the Earth.**
  - Erosion. How brought about. Effects on eroded material. Gorges and cañons.
  - Transportation. Transporting power, how increased. Quantity of matter carried down by the Rhone and the Mississippi. Deposit of eroded material, by what occasioned.
  - Results of deposit. Changes in river-courses, how caused. Bars, how formed. Deltas, how formed. Remarkable deltas. Formation of, how prevented in some cases. Branching of rivers.
- **4. Relation of Rivers to Ocean Life.**
- **5. Lakes.**
  - Formation of. Cause of overflow. Salt lakes. Cause of saltness. Examples. Inland seas.
- **6. Offices of Lakes.**
- **7. Distribution of Lakes.**
  - In each of the continents.

TEST QUESTIONS.—If the soil were everywhere equally permeable to water, how would that affect the springs? What kind of springs may rise higher than their source, and why? Why are mineral springs so called? How can the water supplied by rivers make the ocean salter? What might prevent the floods of the Rhone? Largest inland sea in the world? Largest body of fresh water?

III. DRAINAGE.

1. Advantages of Drainage.—The second great office of rivers is to drain the land.

Any portion of the globe, to be well adapted for human occupation, requires to be drained. As a rule crops do not flourish in a cold, damp soil; and precisely so human health and strength canno general be maintained where the ground is al wet. The vicinity of swamps is unhealthy.

For this reason a very large area of the su peninsula of Italy, called the Campagna, is al uninhabited. From the days of ancient R until now it has remained, owing to the nature of the land, and the consequent absen any stream into which the waters might directed, a vast swamp and a breeding groun pestilence.

2. How Drainage is Effected.—Drai is accomplished by two combined causes: (1) evenness of the land; (2) the flow of rivers.

The mountains and slopes of every cou determine in a large measure the number o water-courses, their length and direction, and velocity of their currents—in a word, their capa for carrying off superfluous rain-water.

The rivers are the channels through which water carried from the sea in the form of v and rained upon the land finds its way bac the sea. Every running stream may therefor regarded as a kind of rain-gauge, which meas in a general way, the quantity of rain that upon the valley which it drains.

The region drained by a river-system is ca the *river-basin*. The basins of large streams hundreds of thousands of square miles in That of the Mississippi contains nearly 1,250 square miles.

The limits of a river basin are defined by are termed *water-sheds, i.e.*, water-divides, being from a German word meaning to divide. water-shed is a line of elevation, sometimes and sometimes low, which, like the ridge of a divides the rain as it falls, and causes one por to descend one slope of a country or continent, the other portion another.

If on a map of North America you trace a pencil round the sources of all the rivers that pour into the sissippi from the Appalachian slope on the one side, and the Rocky Mountain slope on the other, you will marked out the water-sheds which define the eastern western limits of the Mississippi basin.

The aggregate amount of water discharged the ocean by all the rivers of the world is c puted at more than two and a half million c yards per second. All this volume of water, vast for us to conceive of, is being incess removed from the surface of the ear render and keep it suitable to be th This shows how busily and gran machinery works.

INUNDATIONS.—The in sionally submerge large ar destructive to life and property, occur where the quantity of water to be removed exceeds the capacity of the draining rivers. Many rivers, as the Nile, the Orinoco and the Mississippi, are subject to periodical overflow. So extensive are the inundations of the Po that the Italian engineers have actually proposed a scheme for cutting an artificial channel to be used in case of emergency.

TOPICAL ANALYSIS.

III. DRAINAGE.

1. **Advantages of drainage.**
2. **How drainage is Effected.**
   - River-basins. Water-sheds. Quantity of water delivered by rivers. Cause of inundations.

TEST QUESTIONS.—Which of the oceans receives the greatest amount of drainage? What ocean is without a single river flowing into it, so far as known?

IV. CONTINENTAL DRAINAGE.

[For Map see p. 62.]

1. North America.—The bounding waters of North America are the Arctic Ocean, the Pacific Ocean, and the Atlantic, including the Gulf of Mexico. These receive the drainage of the continent.

The great water-shed is the Rocky Mountain system. It acts like the ridge-pole to the roof of a house, shedding the water to the east and the west. All the region lying westward of it is drained into the Pacific and into Bering Sea by the Colorado, the Columbia, the Frazer, the Yukon, and other rivers of less importance.

East of the Rocky Mountains the continent is divided by the Height of Land and the Appalachian Mountains into three slopes: a northern inclining toward the Arctic Ocean; an eastern toward the Atlantic; and a southern toward the Gulf of Mexico.

The region lying north of the Height of Land is drained by the Mackenzie, and Saskatchewan, and by certain streams which enter Hudson Bay. Southward of the Height of Land we have the great basin of the Mississippi, the drainage of which is poured into the Gulf. This basin embraces all that enormous area which lies between the Rocky Mountains and the Appalachians.

The amount of water carried by the Mississippi from this region into the Gulf of Mexico every second is 675,000 cubic [illegible] about 18 acres of ground to the depth [illegible] how soon the Mississippi [illegible]mp, if it were a dead [illegible] rivers.

[illegible]nt, including [illegible] Great Lakes, is drained by the St. Lawrence and by a series of rivers large and small which flow from the Appalachians to the Atlantic.

2. South America.—The drainage of South America, like that of North America, is mainly effected by three river systems. *The crest of the Andes is the great water-shed.* It lies along the western edge of the continent. Hence the drainage has in general an easterly flow.

The eastern slope embraces nearly the whole of the continent. It is naturally divided into three great river basins, those of the Orinoco, the La Plata and the Amazon. The last contains *the greatest river system on the globe.*

The Amazon discharges six times as much water as the Mississippi. In respect to volume it is the largest river in the world. It rises in the beautiful little lake of Lauricocha, high up among the Andes. Descending by falls and rapids, it reaches the alluvial country below, and then becomes a stream navigable for large steamers from the foot of the mountains to the sea, a distance of about 2,200 miles.

So great is the force of its current that its fresh waters are carried a distance of about 200 miles into the sea. An ocean current passes near its mouth, and sweeps away sediment as fast as the river brings it down. Thus the river's own current and the ocean current prevent the formation of a bar.

The western slope of the continent is steep and narrow. There is no room for long, and no water for large rivers. The Pacific receives only a few small mountain torrents, fed by the melting snows of the Andes.

3. Europe.—From a point in the Ural Mountains at about latitude 61° north, to the Valdai Hills, thence in a south-westward direction through Central Europe down to the southern shores of Spain, an irregular line may be traced which will separate Europe into two great slopes. The one inclines to the northwest, the other to the southeast.

All the rivers have one or the other of these two general directions; and the continent is drained into the Mediterranean, the Adriatic, the Black and Caspian Seas on the one side; or into the Atlantic and Arctic Oceans, and the North, Baltic and White Seas on the other.

The region of the Alps is drained by four streams, the beautiful Rhine of the Germans, the Rhone, the Danube and the Po; the drainage of the Low Plains is accomplished by a number of rivers, among which the Volga, the Don, the Dnieper and the Dniester are conspicuous.

4. Asia.—The continent of Asia, like that of Europe, may be regarded as consisting of two great slopes, one having a general incline toward the north, the other toward the south and east.

Beginning on the western shore of Asia Minor, a line may be drawn to Mount Ararat, thence along the crests of the Elburz and Hindoo Koosh Mountains, thence north-eastwardly to the Sea of Okhotsk, which will represent the great water-shed of the continent.

Southeast of this line the Euphrates and Tigris, the Indus, Ganges, the Yang-tse-Kiang, the Hoang-Ho and Amoor carry the drainage to the southward and eastward into the seas and bays of the Pacific and Indian Oceans.

On the northern side of the line nearly every important river flows in a northerly direction into the Arctic Ocean.

5. Africa.—The drainage of Africa is accomplished in the main by the four great river systems of the Nile, the Niger, the Congo and the Zambesi. Much of the surplus water of the continent, however, is removed by evaporation.

6. Australia.—Australia is scantily supplied with rivers. The Murray and its tributaries are the only water-courses of importance, and, in its lower course, the Murray is sometimes reduced in the dry season to a mere chain of stagnant ponds.

TOPICAL ANALYSIS.

IV. CONTINENTAL DRAINAGE.

1. **North America.**
2. **South America.**
3. **Europe.**
4. **Asia.**
5. **Africa.**
6. **Australia.**

Physical divisions of the surface and resulting drainage.

TEST QUESTIONS.—Largest river that flows into the Atlantic? Pacific? Into the Indian Ocean? Largest river in the world that does not reach an ocean? What river of North America corresponds in magnitude and location to the Orinoco of South America? To the La Plata? What might be the effect if the Great Lakes of Africa were at Khartoom instead of near the Equator?

THE SEA.

The most interesting feature in the drainage system of Africa is the river Nile. But for it Egypt would be as barren as the Great Desert of Sahara. The river is formed by the junction of two streams called the White and the Blue Nile. The former issues from the Equatorial Lakes. The latter rises among the hills and the table-lands of Abyssinia.

During June, July, and August the rains pour down in torrents upon the regions drained by these streams. Each is flooded. Uniting at Khartoom the descending torrents reach Cairo by the middle of June, and during the latter part of summer and in the autumn the land of Egypt is under water.

As the flood subsides a layer of fertilizing sediment is deposited upon the soil. Most of it has been washed down from the Abyssinian hills by the Blue Nile, which takes its [illegible]he color which the sediment imparts to its waters.

V. THE SEA.

1. Extent of the Sea.—Nearly three-fourths of the earth's surface are covered by water. This surface comprises, in round numbers, an area of 197,000,000 square miles, of which about 53,000,000 are land, and 144,000,000 water. All of the land, except 13,000,000 square miles, is on the north side of the equator. The northern hemisphere therefore contains three-fourths of all the known land, and two-fifths only of the water-surface, of the world.

The extent of water that is visible to the eye at one time is not great. If we stand on the shore and look seaward our view is closed in by a line in which sea and sky appear to meet. To this line we give the name *horizon, i.e.*, bounding line. Its distance from us depends on our elevation. If we occupy a position which is elevated six feet above the sea-level our horizon will be three miles off. If we ascend a bluff or lighthouse, and so gain a point about 100 feet high, our horizon will be twelve miles distant.

2. *Saltness of the Sea.*—Various solid ingredients are found dissolved in sea water. Of these the most abundant is what we call common salt. Others are certain compounds of lime, magnesium, potassium and iodine. The solid ingredients may be estimated on an average as about one-thirtieth part of the whole by weight.

Though there is little variation from the average, yet it seems to be well ascertained that within the regions of the trade winds (see p. 76.) the proportion of saline ingredients is greater than elsewhere. This is natural, since there evaporation* is at its maximum. Near the poles the proportion of saline material is less; and just at the equator, owing to the constant rainfall (see p. 92), it is as low as at the poles.

3. *Origin of Saltness.*—Supposing the water of the sea to have been originally all fresh, it is easy to see how in the lapse of time it can have become salt. The case of the sea may be compared to that of a lake with no outlet. All the rivers run into the sea and carry into it immense quantities of saline matter. The amount thus contributed during the past ages of the world's history would be simply inconceivable—amply sufficient to account for the present saltness and density of the waters of the sea.

Another theory is, that when the vapory materials constituting the earth were originally condensed (see p. 7), the saline substances were among the last to be condensed and deposited. Following soon after these watery vapor was condensed, and falling as rain washed the saline deposits into the ocean-basin. According to this view the sea was salt from the beginning.

4. *Color of the Sea.*—The sea is green, or blue; it is sometimes colored here and there by reddish, or whitish, yellowish, or crimson patches, according to the tints imparted by the color of the bottom, by the shadow of the clouds, by the ingredients of its waters, or by its myriads of organisms. In certain parts of the Indian Ocean the waters, as seen from a distance, are black.

In the Mediterranean, in the Gulf Stream, and between the tropics generally, the sea waters are dark blue; along the shores and near the mouths of great rivers and in coral seas they are green.

Thus the sea assumes here and there various shades of color; yet its waters, when taken by the tumblerful, are as clear as the purest crystal.

PHOSPHORESCENT SEA.

5. *Phosphorescence.*—In most parts of the sea the water is phosphorescent. The phosphorescence is caused by certain animalcules, which, like glow-worms and fire-flies on the land, have the power of emitting light, some in flashes, and some in a steady glow. These little creatures are invisible to the naked eye, but they are as multitudinous as the sand, and as beautiful as the stars.

In tropical seas and in certain waters they tip the waves with flame, and cover the sea after dark with sheets of light. As the ship ploughs these waters, she leaves a bright streak far behind in her wake.

Though we cannot see the dolphin and other fish, as they sport in the depths of these phosphorescent seas, yet, by the streaks they leave behind, we can often track them through the water, as we do rockets through the air. As they chase each other in the mazes of their sport, these threads of light are, to those who are fortunate enough to see them, among the most pleasing wonders of the deep. They are particularly beautiful in the harbor of Callao.

6. *The Temperature of the Sea* is in general highest near the surface. In the equatorial waters the average surface temperature is about 80° Fahr., sometimes rising in the Indian Ocean to 90° Fahr., and in the Red Sea to 94°. Towards the bottom the temperature is depressed. Indeed, near the bottom all over the globe deep-sea water seems to be about as cold as that of the Polar seas.

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* Evaporate a small portion of sea water until it is very much concentrated. Then take a drop of this concentrated fluid and put it on a piece of thin glass under a microscope. You will see the saline substances which have given the sea water its peculiar taste crystallizing in regular shapes as the water gradually dries from the glass.

The variations at the same place between the winter and summer temperature of the sea rarely exceed 10°. Thus, in Polar seas, the surface-water is seldom above 42°, nor in intertropical below 68°.

7. Offices of the Sea.—(1) The sea receives the drainage of the land; (2) it wears away or builds up the land; (3) it supplies the atmosphere with moisture; (4) it is one of the great regulators of climate; (5) it is the highway of the nations. Commerce, civilization and Christianity have been wafted on its bosom to the ends of the earth.

TOPICAL ANALYSIS.

V. THE SEA.

- **1. Extent.**
  - Comparative sea area in northern and southern hemispheres. Extent of water visible at one time.
- **2. Saltness.**
  - Due to what ingredients. Quantity of saline matter. Variation of saltness with distance from the Equator.
- **3. Origin of Saltness.**
- **4. Color of the Sea.**
- **5. Phosphorescence.**
  - Cause. Beautiful effects.
- **6. Temperature.**
  - Surface temperature in Equatorial regions. Deep bottom temperature. Variation with the season.
- **7. Offices of the Sea.**

TEST QUESTIONS.—Why should the sea be saltest where evaporation is greatest? Why should it be coldest at the bottom, while the land grows warmer as we descend? Why should the Red Sea be warmer than the Indian Ocean? Why does not a glass of sea water show the same color as the sea itself?

VI. THE OCEANS.

1. The Oceans.—The sea is one immense body of water encircling the globe. It is, however, divided by the intervening land masses, or continents, into smaller bodies, called *oceans*. Of these the Pacific is the largest. It contains more than half the water of the sea. Next in size, but only about half as large as the Pacific, is the Atlantic. The Indian is the third in area. The Arctic is properly only an extension of the Atlantic, while the Antarctic hardly deserves to be regarded as distinct from the main body of the sea.

OCEAN BASINS.—The form of each ocean basin depends naturally upon the shape of the enclosing continents. The Pacific approaches the oval; the Atlantic has been compared to a long trough; the Indian is triangular, while the Polar oceans cannot be said to have any describable shape.

Of all the oceans the Atlantic is the most marked by indentations of its shores. The Asiatic edges of the Pacific and Indian oceans are also well supplied with bays and border-seas.

2. Depth of the Oceans.—Two questions connected with the subject of ocean basins have been within a few years made matter of accurate investigation—their depth and the configuration of their bottom.

The average depth of the Atlantic is about 12,000 feet. It seldom exceeds 18,000 feet, or 3½ miles. The deepest sounding has been made near the island of St. Thomas. It was 27,366 feet, or rather more than 5 miles.

The Pacific has a somewhat greater average depth than the Atlantic. Like the Atlantic it has deep abysses. One near the Kurile Islands is the very deepest part of the ocean yet accurately measured. Soundings of 27,930 feet were made.

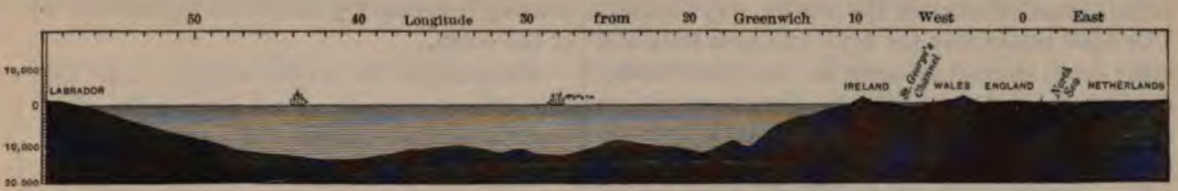
3. The Bottom of the Ocean is, like the land, diversified with hill and dale. Vast plateaus, banks, and shoals spread themselves out; and islands rise from the ocean depths far more abruptly than mountains do on the land.

San Domingo and many other islands of the sea rise from the bottom to the surface almost perpendicularly. The Silla de Caracas, on the other hand, which is the steepest mountain in the world, rises at an angle of 53°.

BED OF THE ATLANTIC.—The bed of the Atlantic has been more thoroughly examined than any other. It seems to consist of two nearly parallel valleys extending north and south and separated by a lofty dividing ridge. The islands which are scattered along its length are the summits of this ridge. That portion of the Atlantic bed to which the name of *Telegraphic Plateau* has long been given is of special interest. This plateau stretches entirely across from Newfoundland to Ireland, at an average depth of somewhat less than two miles.

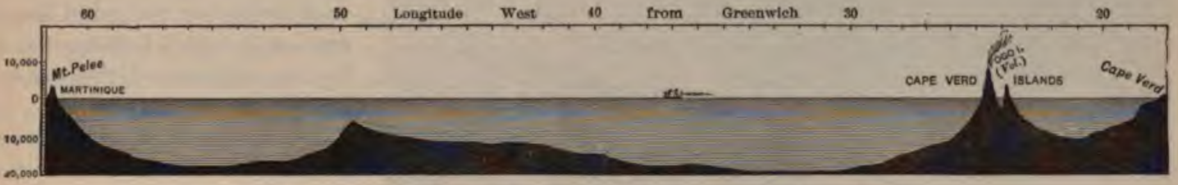
If we imagine ourselves walking across it from Newfound-

NOTE.—The practical value of the information derived from the Atlantic deep-sea soundings was early appreciated by the author of this book. Almost as soon as the results of the soundings were made known to him, he saw that the laying of a telegraphic cable was a practicable project. He was the first to suggest and urge the carrying out of this scheme, the accomplishment of which has been one of the grandest achievements of modern science. To Maury belongs the glory of having pointed out a highway under the waters, whereby the ends of the world have been brought into instantaneous communication.—THE REVISER.



VERTICAL SECTION OF THE ATLANTIC OCEAN AT 52° NORTH LATITUDE.

land to Ireland, we shall first descend by an easy slope to the Grand Banks. Here the depth is about 1,000 feet. Leaving the Grand Banks we shall pass quite rapidly to the depth of about 13,800 feet. From this point there is not much variation in the depth for about half-way across the ocean. When however, we have performed half our journey, we shall ascend again, first rapidly and then gently, until we reach the neighborhood of the British Isles. For a distance of about 230 miles westward of Ireland the upward slope is very gradual until we gain the dry land.



VERTICAL SECTION OF THE ATLANTIC OCEAN AT 14°48′ NORTH LATITUDE.

Bed of the Indian Ocean.—The soundings taken in the Indian Ocean indicate that the configuration of its bed is not unlike that of the Atlantic. It is deepest between Java and Australia.

It is believed that two valleys similar to those of the Atlantic traverse this ocean. As in the Atlantic they are nearly parallel and extend in a north and south direction, while a ridge indicated by the Laccadive, Maldive and Chagos Islands separates them.

Bed of the Pacific.—Of the bed of the Pacific we have little accurate knowledge. Judging from the multitude of islands, great and small, which diversify its surface, we know that a corresponding number of rock masses, miles in height, and shaped like gigantic columns, must rise abruptly from its floor.

The cruises of the Challenger and Tuscarora revealed the fact that in the bed of this ocean are the greatest depths hitherto measured. The deepest soundings of the former showed a depth of about $5\frac{1}{5}$ miles ; those of the latter, about $5\frac{1}{4}$. No complete survey has, however, been made as yet.

TOPICAL ANALYSIS.

VI. THE OCEANS.

- **1. The Oceans.**
  - Number and relative size. Form of basins. Indentation of shores.
- **2. Depth.**
  - Of the Atlantic. Of the Pacific.
- **3. Bottom.**
  - General form as compared with the surface of the land. Bed of the Atlantic. Of the Indian Ocean. Of the Pacific. Practical value of deep-sea soundings upon the intercourse of nations.

Test Questions.—How does the average depth of the ocean compare with the average height of the land ? [see p. 27.] Why should islands rise more perpendicularly under the water than mountains do on the land ?

VII. WAVES AND TIDES.

1. Waves.—"The troubled sea that cannot rest" has ever been the emblem of unending movement. Waves, tides, and currents incessantly disturb it.

Waves are caused by the wind.—The wind strikes upon the surface of the sea, and thus produces an alternate downward and upward movement of its waters. A mass of water moved in this way is called a *wave*. The elevated portion of the water is called the *crest* ; the distance from one crest to another is the *breadth*. The depression between two crests is called the *trough*.

Wave-movement.—The rolling in of waves upon the beach produces the impression that the entire body of water is moving toward the land. As we shall see, however, when we come to consider the subject of tides, it may actually be receding. We must, therefore, distinguish between the motion of the wave-movement and the motion of the water.

To illustrate : If we produce a ripple upon the surface of water in a basin, bath, or pond, the ripple will travel from edge to edge of the water, and communicate an undulating or wave-movement to each portion of the surface. But the water itself has no progressive movement.

The action of a breeze upon a field of wheat, or tall grass, illustrates the matter very forcibly. The wind passes over the field, and each stalk and blade bends alternately down and up, thus forming depressions and wave-crests. Yet there is no onward movement of the stalks. It is only the motion that travels.

Those portions of the water, however, which actually reach the shore, do possess an onward movement. Instead of being driven against an adjoining mass of water, they encounter the solid bottom. Thus the lower part of their mass is retarded, while the upper part moves onward, curls over, and dashes as a *breaker* upon the beach.

WEARING AWAY OF THE ROCKS.

THE HEIGHT OF WAVES depends mainly upon the force of the wind, and the depth of the water. In general they are not more than 8 or 10 feet high. The highest known are those off the Cape of Good Hope, where they are said to attain the height of more than 40 feet.

THE VELOCITY OF WAVE-MOVEMENTS depends (1) on the velocity and force of the wind; and (2) upon the depth of the water, and its freedom from obstructions. In the open sea the advance of a wave-movement is more rapid than in one obstructed with islands. The rate of wave-travel is estimated at from 15 to upwards of 50 miles an hour.

EFFECT OF WAVE-MOVEMENTS.—*The wave-movements of the ocean are incessant.* Even where a perfect calm prevails, there is a ceaseless movement of the water, which, like a great pulse, keeps the surface constantly rising and falling. This heaving is commonly known as the ***ground swell*** of the ocean.

Waves affect the surface chiefly. The highest waves in a storm have no appreciable effect in water more than a quarter of a mile in depth. A wave 40 feet high and a quarter of a mile in breadth would not, in all probability, disturb the smallest grain of sand lying on the sea-bed at a depth of 200 fathoms.

2. Force and Work of Waves.—The heaviest billows beat against the shore with a force varying from 600 to 6,000 lbs. to the square foot. They dash the rocks to pieces, and grind them into sand, which is transported by the currents of the sea to other parts of the world.

All the sand, many of the stratified rocks, much of the clay and soil, with which the rocky skeleton of the earth is clothed, have at one time or another been broken or pulverized by the action of water.

The waves have erected on some shores *dunes* or hills of sand; elsewhere they have filled up harbors. On the shores of the Bay of Biscay whole villages have been overwhelmed.

3. The Tides *are gigantic wave-like movements.* They differ from windwaves, (1) in their extent; (2) in their regularity; (3) in their cause. In a general way it may be said that two vast waves, each having its crest and its depression, together encircle the globe from north to south. These two ceaselessly chase one another over the broad expanse of the sea, occasioning two elevations and two depressions of its waters in the course of about twenty-five hours.* From the fact that these elevations and depressions occur with regularity about one hour later each day, and thus rudely mark the time, they are called *tides*, from the Anglo-Saxon *tid*, time.

The elevation or rising of the water is called *high* or *flood-tide*; its depression or falling, *low* or *ebb-tide*. These occur alternately every six hours.

4. Cause of Tides.—*The tides are mainly due to the influence of the moon.* The sun also has a tide-producing power, but it is insignificant compared to that of the moon, owing to the fact that the sun is 400 times farther off from the earth than the moon is.

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* The exact time is twenty-four hours, fifty minutes, or what is known as a lunar day, *i.e.*, the time between the crossing of the meridian of a place by the moon and her being on the same meridian again.

The moon is comparatively near to the earth. Let us see then how, in consequence of this, she affects its waters.

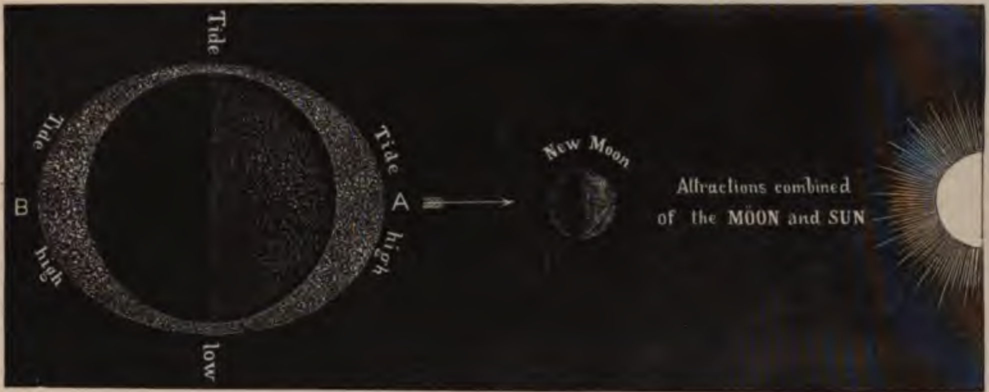
High Tides.—As represented in the illustration, the opposite sides of the earth have high tide at the same time, and low tide at the same time. High tide occurs at *A*, on the side of the earth toward the moon, for this reason; the moon is nearer to the water on that side of the earth than it is to the centre of the earth. Hence the moon attracts the water more powerfully than it does the earth, and the water bulges forward as a high tide.

But why is it high tide also at *B*, on the opposite side of the earth? In this case the general mass of the earth is more powerfully attracted by the moon than the water is, and the effect is as though the earth were drawn away from the water; so that here also the water bulges forward as a high tide.

tide-producing forces. Hence we have what are known as the *spring tides*. During these the flow is at its maximum. When, on the other hand, the moon is entering her second and her fourth quarters, the two forces do not act in harmony, and we have in consequence the *neap tides*, in which the flow is greatly less than in the spring tides.

5. Origin of the Tidal-Wave.—In pursuance of regulations established some years ago by the authority of the British government, observations were made upon the tides, night and day, for a whole month, in all parts of the world. These observations led to the conclusion that *the tidal-wave has its cradle in that great expanse of ocean that surrounds the Antarctic region.*

6. Movement of Tidal-Wave.—Starting at the point of its origin, let us observe the progress of the tidal-wave as it passes from ocean to ocean round the globe.



SPRING TIDES.

Low Tides.—Half-way between the tidal wave-crests or high tides, there are depressions, as represented in the illustration. These occur where the water is drawn away to form the high tides. They create the low tides. Like the high tides they take place twice in a lunar day, at intervals of a little more than twelve hours.

Evidence.—Evidence that the moon chiefly is concerned in causing the tides is to be found in the facts (1) that high tide occurs at any place nearly at the time when the moon is over the meridian of the place; and (2) that, at full moon and new moon, the tides are higher than usual.

SPRING AND NEAP TIDES.—A marked phenomenon of the tides is that the intensity of the movement varies. Three days after full and new moon the flow or rise of the water is far greater than usual. This is explained by the fact that when the moon is new, as in the illustration, and when she is full, the sun and moon combine their

The "chart of co-tidal lines" on page 59 will be found useful in doing this. These lines connect places which have high tide at the same time. They represent the crest of the tidal-wave. In the waters about New Zealand, the birth-place of the tides, and to the northward as far as the Tropic of Cancer, they show that the tidal-wave extends nearly north and south. As it advances, portions of it are retarded, or deflected or even repelled by reefs, islands, or continental shores.

The deeper the water, the more rapid is the rate of the tidal-wave. This is indicated by the bulging of the co-tidal lines. The distance between any two lines is the distance traversed in an hour.

With our eye upon the chart, let us now follow the movements of the tidal-wave in the three great oceans, the Pacific, the Indian, and the Atlantic.

PACIFIC OCEAN.—In the Pacific Ocean the tidal movement is more regular than in either the Indian or the Atlantic. The general course of the wave, however, instead of being due west, is north-westward. The long crest extends across the expanse of the ocean, and advances toward the shore of Asia. In three hours after it has broken upon the coast of New Zealand, it reaches Sydney and Tokio.

The islands and continental masses on either side of the Pacific basin retard its movement, whereas in mid-ocean, as indicated by the bulging of the curves, it advances with vastly greater rapidity. When, for instance, its northern extremity has reached San Francisco, its centre has bulged 4,000 miles to the westward.

It will be seen that one portion of the wave is reflected or repelled in a south-easterly direction to the shores of South America. The cause of this is not understood.

INDIAN OCEAN.—In the Indian Ocean we observe the same general phenomena as in the Pacific. The tidal-wave advances to the north-westward. Its centre crosses the main body of the Indian Ocean with rapidity. Its extremities are retarded by the shores and islands which it encounters.

ATLANTIC OCEAN.—In the Atlantic, as in the Pacific and Indian Oceans, the tidal-wave has a north-westward direction. It traverses the length of the ocean from south to north in about twelve hours. It travels, therefore, at the rate of about 500 miles an hour.

Owing to the narrowness of the Atlantic basin and the irregular contour of its shores, the tidal-wave encounters many retarding and deflecting obstacles.

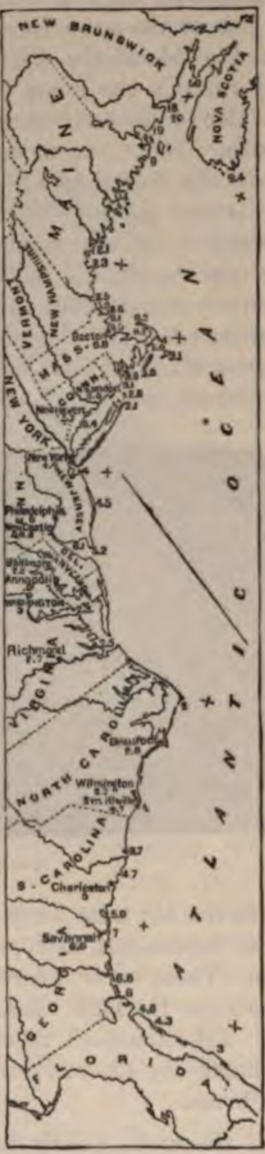
North of the Equator a portion of the wave, following the narrow channel between the shores of Europe and Africa on one side and those of Greenland on the other, assumes a north-easterly direction.

On the western side of the North Atlantic, the tidal-wave travels faster than on the eastern, for the reason, it is supposed, that this part of the ocean is deeper than the other. It reaches Newfoundland on the west in latitude 48° north, when it is no farther on the east than Cape Blanco, in latitude 21° north, on the African shore.

7. *Speed of Tidal-Wave.*—Since the tides follow the moon, they have to travel round the earth from east to west in the same time that she appears to revolve round it, viz., twenty-four hours and fifty minutes. The tidal-wave, therefore, in equatorial seas, would, if it were unobstructed, and could pursue a direct course, travel at the rate of 1,000 miles an hour.

It must be borne in mind, however, that the water in mid-ocean has only an imperceptible progressive motion; it is the movement or undulation, not the water, that travels at this high rate of speed.

The waving grain, as it bends to the breeze, causes an undulation that travels across the field faster than you can run; but the stalks are rooted; they only sway backward and forward to the breeze. So it is with the deep sea and its swell.



ATLANTIC COAST TIDES.
(Mean height, in feet.)

When, however, the tidal-wave comes near the shores, where the water is shallow and confined, a change occurs. The undulation is retarded, but the motion of the water is vastly increased, and it sweeps as a current along the continental shores and up the bays and rivers. The current gains in speed as the tidal-wave loses.

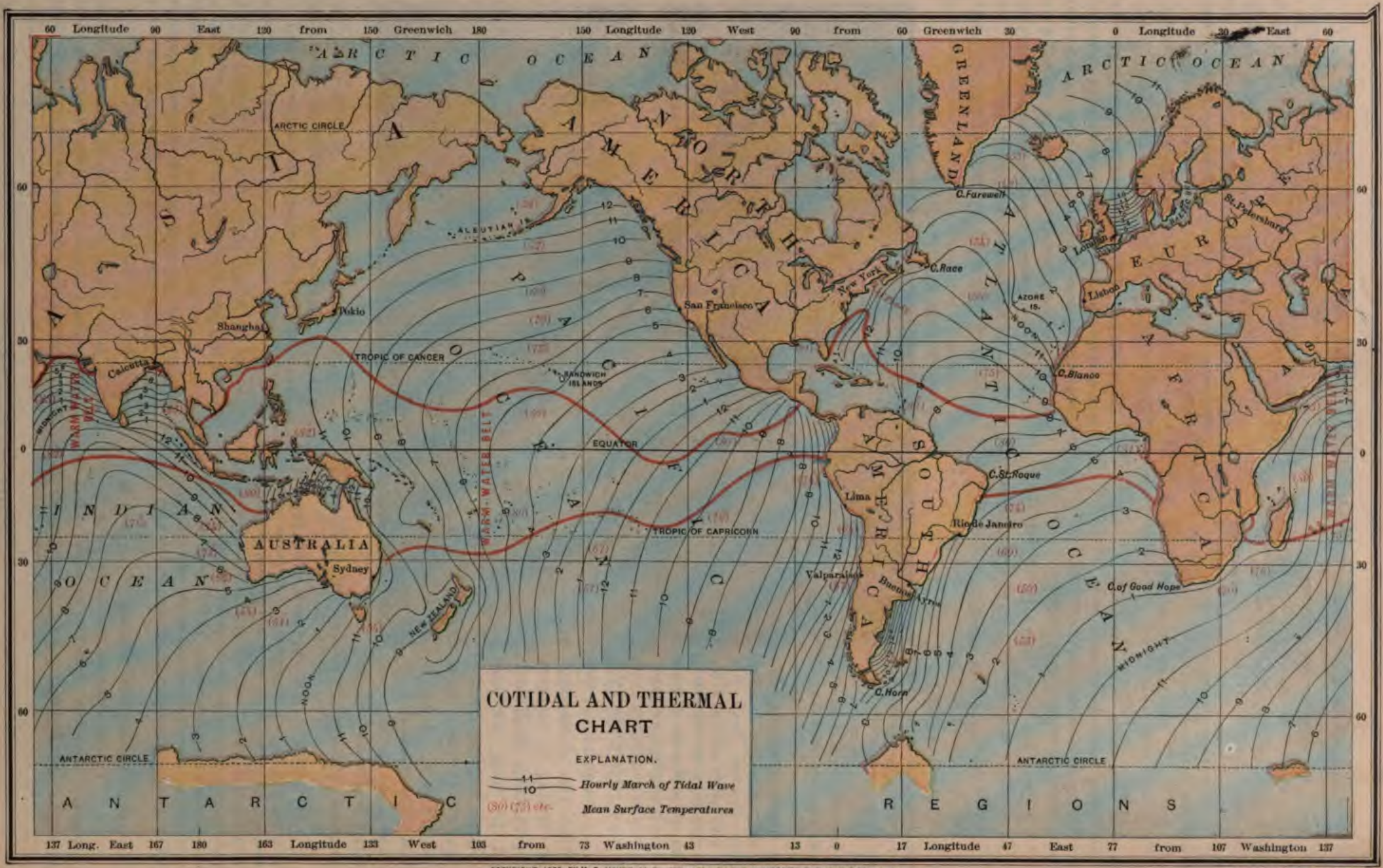
The current often attains unusual speed in passing headlands; and then the term *race* is commonly applied to it. Such an accelerated current moves from six to eleven miles an hour.

8. *Height of Tides.*—In the middle of the Pacific Ocean the rise of the tide is sometimes less than a foot; in the Atlantic, near St. Helena, about three feet. On the other hand, between the converging shores of narrow seas and bays the water is sometimes heaped up to the height of from twenty-five to forty, and, in the Bay of Fundy, from 50 to 60 feet.

The Mediterranean and the Red Seas, however, with their narrow and shallow entrances, almost cut off the tidal-wave of the ocean, so that neither in the eastern part of the Mediterranean, nor at the head of the Red Sea, is there any regular ebb and flow of tides.

In the Caribbean Sea and Gulf of Mexico, likewise, the tides are quite feeble, owing probably to the fact that these sheets of water are protected from the tidal-wave by the West Indies.

DIFFERENCES ON THE SAME COAST.—Very great differences exist between the tides at various points of the same coast. On the shores of Florida the



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rise is not more than about three feet. It increases as we go northward, until we reach the Bay of Fundy, where it attains its maximum. [See Chart, p. 58.]

At some points on the shores of Great Britain there are tides of great height and strength, while at others close by, the rise and fall are barely perceptible.

The rise and fall at Liverpool are 28 feet; in the Bristol Channel, 40 feet; at Wicklow, on the opposite Irish coast, only two or three.

Causes.—To account for these differences various causes may be suggested: the form of the bottom, the projection of headlands, the narrowing of channels along which the tidal current is forced, and the position of those channels with reference to the direction of the tidal wave.

THE "BORE" OF THE TSIEN-TSANG RIVER.

A glance at the map shows, for example, that were the tidal-wave propagated from the northeast instead of the southwest, the Bay of Fundy would cease to be celebrated for the height of its tides.

The peculiarities of a shore are sometimes such as to cause a complete sundering or division of the tidal waters. Two currents are thus formed. In some cases these meet again after their division and give rise to a *whirlpool.* Charybdis in the Straits of Messina, and the Maelstrom among the Lofoden Isles, are illustrations of this phenomenon.

9. Tides of Rivers.—The tides of some rivers present interesting peculiarities.

They enter certain river channels with extraordinary velocity. People crossing the dry bed of the river Dee, in England, are often overtaken and drowned by the inrushing water.

The case of the Amazon is of special interest.

The tides ascend this river to a greater distance from the sea than any other in the world. Tide-water extends in it 700 miles up the current; and the singular phenomenon is presented of there being several tides (Sir John Herschel says eight *) in the river at the same time; for before the flood of one has reached the end of its 700 miles' journey, several other tidal waves, each in succession bringing high tide with it, have had time to enter.

BORES.—A tidal-wave of great height sometimes enters the mouth of a river and ascends its channel as a perpendicular wall of water. Such a tidal-wave is known as a *bore.* Among the most remarkable are those of the Hoogly at Calcutta, the Garonne in France, the Tsien-tsang in China, and the Amazon.

At certain times bores 12 to 15 feet high come rushing into the channel of the Amazon on the top of the tide. Sometimes as many as five, 30 or 40 miles apart, dash up the river, capsizing small craft as they go and spreading consternation among the watermen.

The bore of the Tsien-tsang is even greater than that of the Amazon. It spans the river with a feather-white and roaring wall of water, 30 feet high, and travels at the rate of 25 miles an hour.

TOPICAL ANALYSIS.

VII. WAVES AND TIDES.

1. **Waves.**
   How caused. Crest of the wave. Breadth. Nature of wave-motion. Height and velocity of ocean waves. Circumstances affecting velocity. Effect of wave-movements. Depth to which the motion extends.
2. **Force and Work of the Waves.**
   Force per square foot. Effect in pulverizing rocks. In causing encroachment of sea lands.
3. **The Tides.**
   General description. Origin of the name. Flood and ebb tides.

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* "Physical Geography," by Sir John Herschel.

4. **Theory of Tides.**
    Cause of high tides. Low tides. Evidence. Spring and neap tides.
5. **Origin of Tidal-Wave.**
6. **Movement of Tidal-Wave.**
    Co-tidal lines. Curving of the lines, how caused. Movement of the wave in the Pacific. In the Indian Ocean. In the Atlantic.
7. **Speed of Tidal-Wave.**
    Of the current.
8. **Height of Tides.**
    Cause of feeble tides in certain waters. Difference in tides on the same coast. Causes. Whirlpools.
9. **Tides of Rivers.**
    Tides of the Dee. The Amazon. Bores.

TEST QUESTIONS.—How is the expression "waves running mountains high" to be regarded? What is the general effect of wave-action along the coasts on the relative area of land and sea? Why do the tides occur a little later every day?

VIII. CURRENTS OF THE SEA.

1. The Currents of the Sea.—There are rivers in the sea. They are of such magnitude that the mightiest streams of the land are rivulets compared to them. They are either of warm or cold water, while their banks and beds are water of the opposite temperature. For thousands of miles they move through their liquid channels unmixed with the confining waters. They are the horizontal movements called *currents.*

The mariner can sometimes detect them by the different color of their stream, while, if they give no such visible sign of their existence, he can trace them by testing their temperature with his thermometer.

CLASSIFICATION.—The chart on pages 62 and 63 exhibits a general view of the oceanic currents. It presents these facts :

(1) there is an *equatorial current* sweeping from east to west all along on either side of the equator, and well nigh encircling the globe ;

(2) there are *polar currents* setting from the polar regions toward the equator ;

(3) there are *return currents* setting from the equator toward the poles.

COURSES OF CURRENTS MODIFIED.—The chart shows that as in the case of the tidal-wave, so in the case of oceanic currents, the shores of continents and islands have marked effect in modifying their normal courses. These are also modified by the rotation of the earth.

Effect of Rotation.—Let us see what the effect of rotation is. If two trains are moving on parallel tracks in the same direction and with the same speed, an object thrown or a ball shot "point blank" from one to the other may strike the point aimed at. But if the train from which the ball is shot be going 85 miles an hour, and the other only 15, the ball from the first will strike in advance of the point aimed at. If the direction of the trains be eastward, then the ball will strike a certain distance to the east of the point aimed at.

This is what occurs when water starts from the equator toward the poles. It rotates toward the east at the speed of 1,000 miles an hour. Passing to either pole, therefore, it has a higher speed of rotation than belongs to the latitudes which it reaches, and hence it has an eastward movement.

If now we suppose the ball to be discharged from the slower train, it will obviously fall behind, or to the westward of the point aimed at. This is what occurs when water starts from either pole to the equator. It has the slower rotary motion of the pole, and, as it approaches the equator, it constantly enters latitudes which have a higher speed of rotation. They pass it by, and it lags to the westward.

Hence currents moving to the poles derive from rotation an eastward trend ; those moving to the equator a westward.

NOTE.—In treating of oceanic currents it is important to observe the method of naming them. A northeast wind *comes from* the northeast, a northeast current *goes toward* the northeast. In other words, while the winds are named according to the points from which they blow, currents are named according to the quarter toward which they flow.

2. Currents of the Atlantic.—We will now consider the currents in the several oceans. For convenience we begin with the Atlantic.

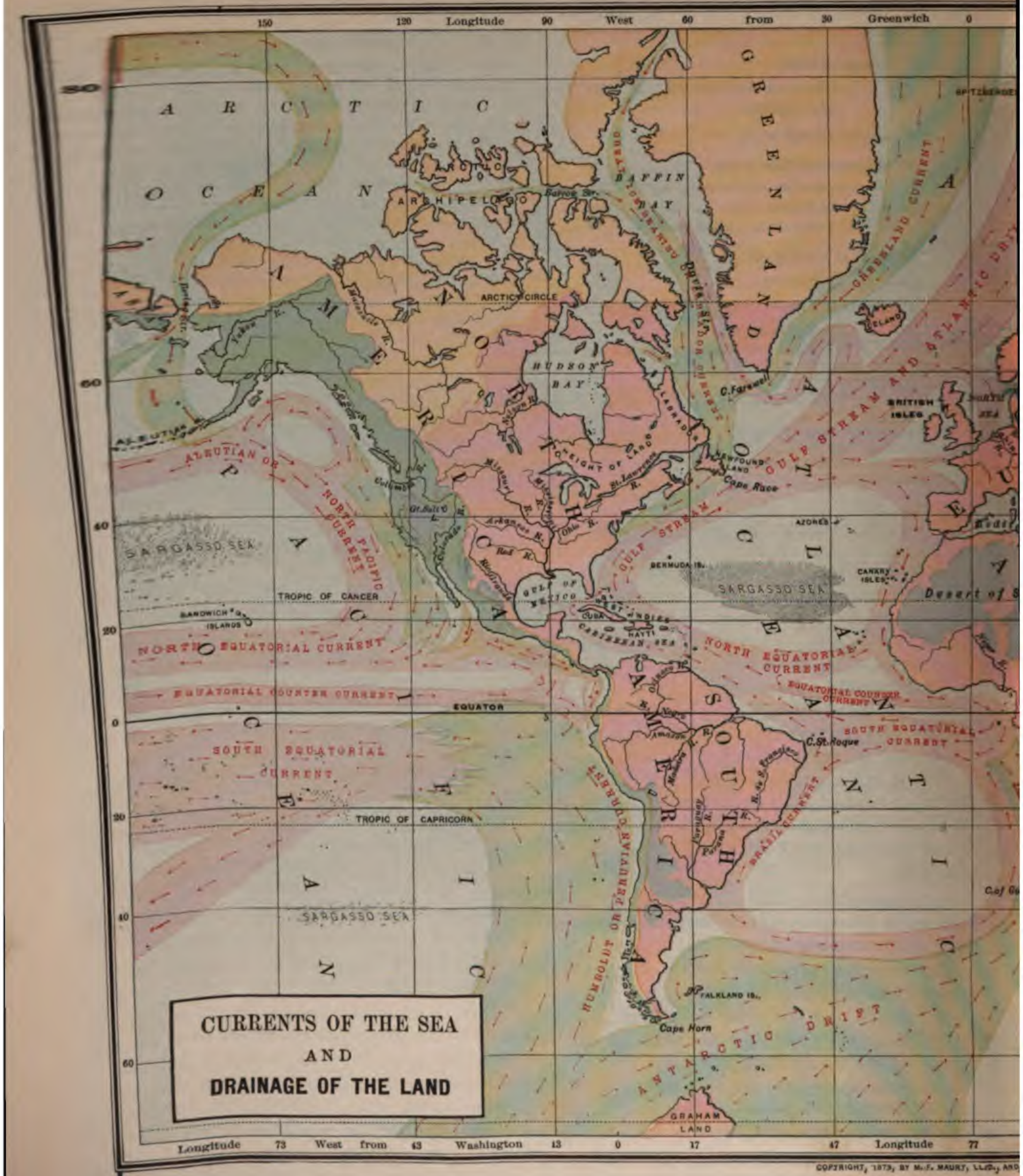
THE EQUATORIAL CURRENT crossing this ocean between the shores of Africa and South America strikes the latter continent at Cape St. Roque. Here it divides. One portion passes southward, following the coast line of South America. It is named the *Brazil Current.* Its waters, reaching the Antarctic regions, are carried back with the polar current which sets along the west coast of Africa, toward the equator.

The other portion of the Equatorial Current, on leaving Cape St. Roque, flows northwestwardly. It is divided by the West Indies. Its main section enters the Caribbean Sea and the Gulf of Mexico, and from these it issues through the Strait of Florida as the well-known *Gulf Stream.*

Between the two branches of the Equatorial Current in all the oceans there is a slight eastward counter current.

THE GULF STREAM.—Among the return currents which carry the ocean waters from the equator to the poles, the Gulf Stream is the most remarkable. Issuing from the tropics, this current crosses the Atlantic in a northeasterly direction. On leaving the Strait of Florida, it takes a course nearly parallel to our Atlantic seaboard. Reaching the latitude of Newfoundland, it turns more directly eastward. (See Recent Facts, p. 1.)

North of the Azores it becomes blended with the northeasterly drift of the Atlantic, and the united current divides. One branch passes southward, skirts the western shores of southern Europe and Africa, and then, veering to the westward, finds its way back into the Equatorial Current. The other passes on to the northeast, bathes the shores



CURRENTS OF THE SEA
AND
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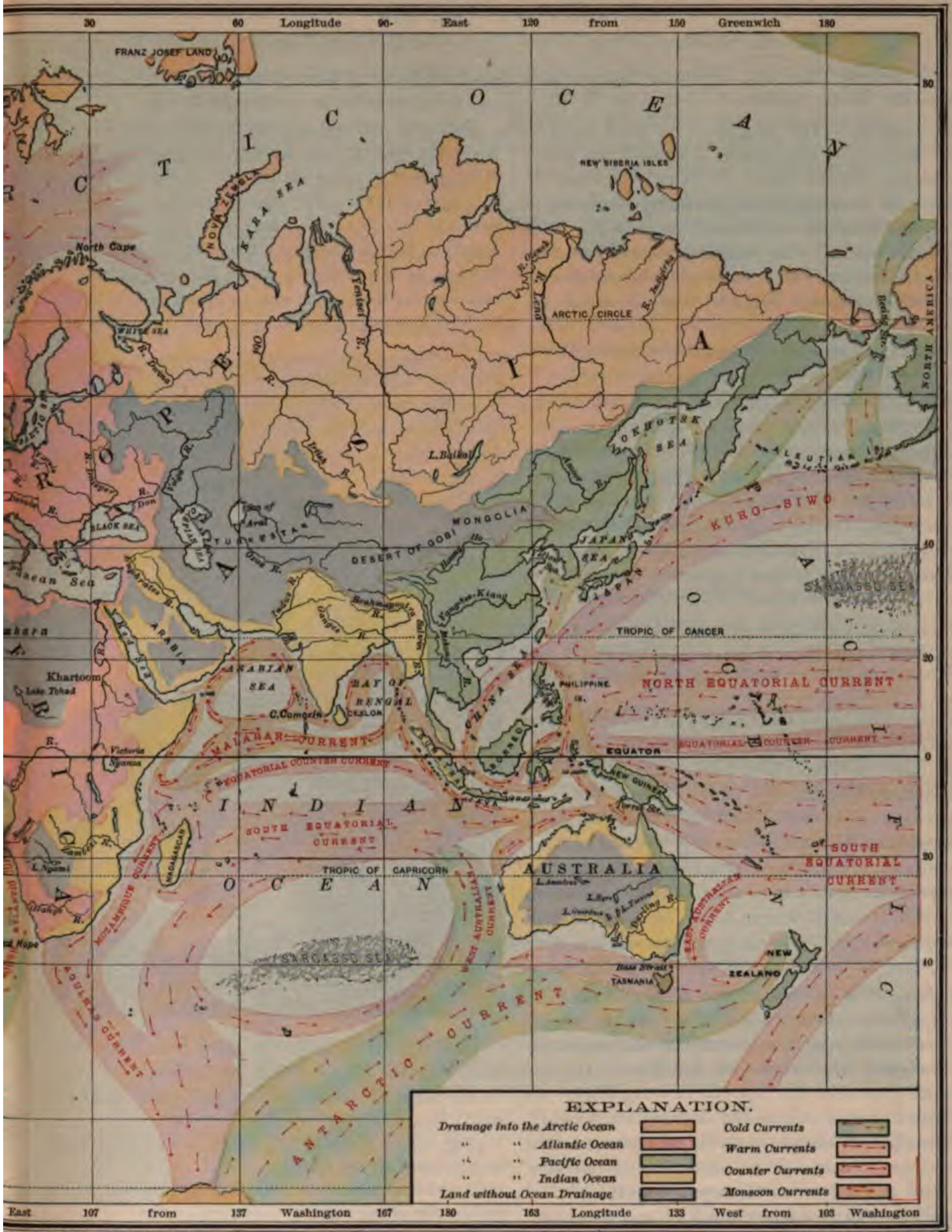
Questions on the Currents of the Sea.

Atlantic Ocean.—What currents carry the Arctic waters into the Atlantic? Trace the course of the Equatorial Current. What does it become east of the United States? Describe the course of the Gulf Stream.

What current bathes the south-eastern shores of South America? Where does it originate? Into what ocean does it pass? What current brings into the Atlantic the water of the Antarctic? Name the warm currents of the Atlantic. The cold currents.

Pacific Ocean.—What currents form the Equatorial Current of the Pacific? Where do they blend? Describe the course of the Equatorial Current. Where does it divide? Name of the southern branch? Of the



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northern? Trace the Japan Current. What name does it receive off the coast of Alaska? Describe its course. Does the current west of South America make the neighboring shores warmer or cooler? Why? Show how the Pacific system of currents resembles that of the Atlantic.

Indian Ocean.—Where do the currents that enter the Indian Ocean come from? Describe the course of the Mozambique Current. Of the Australian Currents. How are the currents affected in the Bay of Bengal and the Arabian Sea?

Where do you find Sargasso Seas? Why should they be where they are?

Tell into what oceans the drainage of each continent passes. What regions have no ocean drainage?

of the British Isles and northern Europe, and enters the Arctic basin.

Dimensions.—The length of the Gulf Stream, from the Gulf to the Azores, is about 3,000 miles. Its breadth in the Strait of Florida is about 32 miles. In its progress it constantly increases in breadth, till, in the middle of the Atlantic, it is 120 miles across. The depth is about 2,400 feet near the straits. This naturally diminishes as the width increases. Off Charleston it is reduced to 1,800 feet.

In volume the Gulf Stream exceeds the Mississippi more than 1,000 times.

The temperature of the surface waters of the Gulf Stream, as they pass the Strait of Florida, is sometimes as high as 85° Fahr. It is a river of warm water, and retains its warmth in a remarkable manner. Off Cape Hatteras, and even as far as the Grand Banks, its temperature is 15°, 20° or even 30° higher than that of the atmosphere.

The storing up of heat begins, no doubt, while the Gulf Stream is a part of the Equatorial Current, and continues all the time that its waters are exposed to the tropical sun, whether in the Atlantic, the Caribbean Sea, or the Gulf of Mexico.

Color.—From the Gulf up to the Carolina coasts the waters of the Gulf Stream are of an indigo blue; and the line which marks the division between them and the edge of the inshore waters is sometimes so sharp that you can distinguish when one-half the vessel is in the Gulf Stream and the other is in the cool littoral waters. The line of demarcation is so well-defined that navigators in the olden times, when both instruments and methods for determining longitude at sea were rude, used to judge by it of their longitude.

Offices.—The offices of the Gulf and Atlantic Drift Stream are two: (1) it carries the waters of the torrid zone into the Arctic Ocean; (2) it is the great heat-carrier of the North Atlantic Ocean.

Such immense volumes of heat are conveyed by this benignant stream to northern latitudes, that the winter climate of the whole western face of Europe, as far north as Lapland, is softened and tempered with genial warmth.

The ponds of the Orkney Isles, though bordering on the parallel of 60° north, owing to this moderating influence, never freeze; and the harbor of Hammerfest, the most northerly seaport in the world, in latitude 70° 40′, is always open.

POLAR CURRENTS.—On either side of Greenland, cold, ice-bearing currents come down from the Arctic Ocean to replace the warm water carried northward by the Gulf Stream. Off the southern point of Greenland these currents unite and advance as far as the Grand Banks.

Here one portion of the united stream sinks below the warmer and lighter waters of the Gulf Stream, and pursues its course to the tropics as an undercurrent. The other portion turns southwest and follows closely the eastern coast of North America, keeping between the shores and the Gulf Stream, as far south as Cape Hatteras, where it passes under the Gulf Stream and continues its way to the equatorial regions mainly as an undercurrent.

BIRTHPLACE OF ARCTIC ICEBERGS.

This current supplies the markets of New England with the choicest fish of the sea, and gives to the coast of Maine its singularly cool summer temperature.

At the Grand Banks the Arctic Current meets the Gulf Stream, and, chilling the vapor which rises from its surface, produces the dense fogs which render this part of the ocean so dangerous to navigation. (See p. 87.)

From the *Antarctic*, as from the Arctic Ocean, there is a constant flow of icy waters into the Atlantic basin. The South Atlantic Current, issuing from the Antarctic Ocean, follows the western shore of Africa, passes northwestwardly, and contributes to form the Equatorial Current of the Atlantic.

3. *Currents of the Pacific.*—Turning now to the Pacific, we find its currents presenting a general resemblance to those which we have noticed in the Atlantic.

An Equatorial Current starts westward from that portion of the ocean lying to the southwest of Mexico. Like the corresponding current of the Atlantic it divides. One branch passes to the southward. Bathing the eastern shore of Australia, it is called the *East Australian Current.* Between Australia and New Zealand it blends with the Antarctic Drift.

The northern branch of the Equatorial Current pursues a course not unlike that of the northern branch of the Equatorial Current of the Atlantic. Passing the Archipelago off the southeast coast of Asia, its main body turns northeastward, and, sweeping past the Japanese Islands, receives from them its name, *Japan Current.* The natives of Japan call it, from the dark blue color of its waters, Kuro Siwo, *i.e., Black Stream.*

The *Japan Current* is the Gulf Stream of the Pacific. Like that stream, it has the twofold office of water-carrier and heat-bearer. It transfers the water of the central and western Pacific to its northern and eastern portions; and with its warm waters it softens the climate of the Aleutian Islands, and of the northwest coast of America, just as the Gulf Stream does that of western Europe.

Passing the Aleutian Islands the main volume of the Japan Current receives the name of the *Aleutian* or *North Pacific Current,* and takes a southeastwardly course. Reaching the coast, it gives to southern Alaska its enormous annual rainfall and its abundant timber growth; it waters Washington and Oregon; and then, veering to the westward, becomes again a portion of the Equatorial Current.

Polar Currents.—A small surface current issues from the Arctic Ocean through Bering Strait. It flows between the Japan Current and the eastern shores of Asia, like the polar current which flows between the Gulf Stream and the shores of America, and, like the corresponding current of the Atlantic, it teems with excellent fish, thereby vastly increasing the capacity of China and Japan to sustain population. It brings down field-ice from the seas of Okhotsk and Bering.

From the Antarctic a broad drift flows toward the equator. Off Cape Horn it divides. One branch passes into the Atlantic; the other, the *Humboldt* or *Peruvian Current,* enters the Pacific.

The Humboldt Current carries its cool Antarctic waters all along the west coast of South America from Patagonia to the Galapagos Islands. These waters, when they touch the equator, are still too cold for the coral polyp to inhabit. Hence the whole western coast of South America is without coral reefs or coral formations of any kind; though in the same latitudes, at a distance from the coast, where the waters are warm, the ocean is alive with the tiny masons of the deep.

Near and at the equator the Humboldt Current is deflected to the westward and becomes part of the Equatorial Current of the Pacific.

4. *Currents of the Indian Ocean.*—The Indian Ocean has no such well-defined system of currents as the Atlantic and Pacific. North of the equator the direction of the flow is determined by the monsoons. South of the equator an Equatorial Current, emerging from the East Indian Archipelago, sweeps to the westward. Reaching Madagascar it branches. The eastern fork passes to the southward and merges with the Antarctic Drift. The western flows along the eastern coast of Africa as the Mozambique Current. Leaving the Mozambique Channel it becomes the Agulhas Current, and south of the Cape blends with the Antarctic waters.

A branch of the Antarctic Current, setting to the northwestward, and becoming the West Australian Current, pours its icy flow into the Indian Ocean.

5. *Counter Currents.*—In each ocean traversed by an Equatorial Current there is a slight eastward counter current.

6. *Oceanic Circulation.*—From this general survey it appears that there is a *complete system of circulation by which the waters of the equatorial and polar regions are incessantly changing place and blending together.*

7. *Causes of Oceanic Circulation.*—The main causes of oceanic circulation are (1) difference of specific gravity;* (2) the influence of the winds.

Difference of Specific Gravity is the *chief* cause.

Wherever the waters in one part of the sea differ in specific gravity from the waters in another part, no matter from what cause the difference may arise, or how great may be the distance between two such parts of the sea, the heavier water will flow, by the shortest and easiest route, toward the lighter; and the lighter, in its turn, will seek the place whence the heavier came.

In other words, *from whatever part of the sea a current runs, back to that part a current of equal volume must flow.*

Changes in Specific Gravity are mainly brought about by (1) heat and cold; (2) evaporation and precipitation.

Effects of Heat and Cold.—Sea-water when heated expands. A given volume of such heated water, if it contain the same proportion of salts as an equal volume of colder salt-water, will weigh less. On the other hand, when sea-water is chilled, it contracts and becomes heavier.

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* Two bodies are said to differ in specific gravity when equal volumes of the two differ in weight. A gallon of salt water, for example, weighs more than a gallon of fresh water. A pint of water weighs about a pound; a pint of quicksilver weighs about thirteen pounds.

The average temperature of sea-water is for polar seas about 35°, for equatorial about 80°. This difference of temperature is permanent, and the difference in specific gravity of sea-water at 35°, and sea-water at 80°, is very great.

The cold of the polar regions, therefore, and the heat of the tropics are two powerful and ever-acting causes which produce constant disturbance of equilibrium in the waters of the ocean. Necessarily there will result from this disturbance a never-ceasing movement of the cold waters toward the warm, and of the warm toward the cold.

Effect of Evaporation.—If you evaporate a quantity of sea-water completely, you have solid saline matter remaining. In proportion therefore to the amount of evaporation going on upon its surface, a body of sea-water will be more or less dense, and consequently more or less heavy.

Effect of Precipitation.—Precipitation, or the process by which moisture is returned to the earth in the form of rain, snow or hail, also changes the specific gravity of sea-water.

If upon any part of the ocean a large amount of rain falls, or if rivers flow into it, the sea-water becomes less salt and therefore lighter.

Illustrations.—Striking illustrations of the effect of evaporation and precipitation in producing currents are furnished by the Red, Mediterranean and Baltic Seas.

The Red Sea lies under a burning sun. It is riverless and almost rainless, while the evaporation from it is enormous. To supply the waste created thereby, a constant current from the Indian Ocean is drawn into it through the Straits of Babelmandeb.

In the Mediterranean also evaporation is very great. Into this sea rains fall and rivers flow. Nevertheless, the supply from them is not sufficient to make up for the loss by evaporation. The deficiency, therefore, comes in through the Straits of Gibraltar as a surface-current from the Atlantic.

The water of these two seas, after it has supplied the winds with vapor, becomes salter and heavier than it was before: it sinks and escapes back into the ocean as an undercurrent.

With the Baltic the case is reversed. There the water which is received from the rivers and the rains, is more than sufficient to balance the loss by evaporation. Here, therefore, we have the diluted and lighter sea-water escaping from the Baltic as a surface-current, while an undercurrent of salter water enters from the North Sea.

We can now appreciate what must be the effect of evaporation and precipitation upon the general circulation of the ocean.

Between the equator and the parallels of 25° north and south there is an area of 112,000,000 square miles. Here there is more evaporation than precipitation. The case is similar to that of the Red Sea.

On the polar side of latitude 50° north and 50° south there is an area of 45,000,000 square miles. Here precipitation is in excess of evaporation. The case is parallel to that of the Baltic.

Now try to estimate the total quantity of water that is taken up by evaporation from the one of these parts of the globe and poured down upon the other, and the disturbance created thereby in the equilibrium of the ocean.

The effort to restore this equilibrium is seen in the currents of the sea and the circulation of its waters.

A more accurate measure of the work done by evaporation is the entire annual rainfall upon the surface of the globe. This is estimated at 186,240 cubic miles, or more than 510 cubic miles a day. Reflect, then, that every day on the average this immense volume of water is being uplifted by the agency of evaporation from the surface of the ocean, and you will be better able to estimate the prodigious influence which evaporation must exert in disturbing oceanic equilibrium and producing currents.

Salts.—If, however, we trace this influence of evaporation and precipitation back to its cause, we find that it is due to the presence in sea-water of the solid matter known as salts. In a sea of fresh water the changes in specific gravity upon which oceanic currents depend could not occur.

For if two portions of fresh water be evaporated, one more than the other, the specific gravity of both will at the close of the operation be the same. But mix with the fresh water a certain amount of common salt; then evaporate one portion more than the other, and a difference in the specific gravity of the two portions at once results.

Just so any diminution of or addition to the saltness of any portion of the sea produces a change in its specific gravity and a disturbance of its equilibrium. Hence currents result.

And thus evaporation and precipitation really owe their power as causes of oceanic circulation to the salts of the sea. The very separation from the sea-water of solid matter for sea-shells and coral reefs is a continuous cause of difference in the specific gravity of the waters of the ocean.

It seems more like a vagary of the fancy than the stubbornness of fact, to say that so great a matter as the circulation of the water in the sea should depend, even in the slightest degree, upon such minute creatures as the little coral-reef builder and his tribe. Yet, look at the great Barrier-reef of Australia, the coral rocks, reefs, and islands of the Pacific Ocean. Contemplate the quantity of matter required to build these structures, and say if the taking of it out of solution be not sufficient to disturb the whole ocean, and put it in motion from the equator to the poles.

Winds a Cause of Currents.—The Trade Winds are considered to be the producing cause of the Equatorial Current and its offshoots.

Blowing incessantly to the westward and meeting over the equatorial regions, they impart to the waters beneath them a gentle but continuous westerly movement. Hence the Equatorial Current.

In those parts of the Indian Ocean that are within the monsoon district the currents are controlled by the monsoon winds. For six months they flow in one direction—for six months in the other. (See Chart of Ocean Currents.)

Other winds produce irregular currents. You may yourselves have observed the effect of the wind upon rivers, ponds, or canals, in piling the water up on one side, or at one end, and blowing it away from the other.

In great storms at sea the winds drive the water before them, and they sometimes pile it up many feet above its usual level.

Our nautical works tell us of a storm which forced the Gulf Stream back into the Gulf, and piled up the water to the height of 30 feet. The *Ledbury* attempted to ride it out. When it abated, she found herself high up on dry land, and discovered that she had let go her anchor among the tree-tops on Elliott's Key.

The Florida Keys were inundated many feet, and it is said the scene presented in the Gulf Stream, on that occasion, was never surpassed in awful sublimity.

The water dammed up rushed out with wonderful velocity against the fury of the gale, producing a sea that beggared description.

8. Office of Ocean Currents.—The great office of ocean currents in general is to modify climate. Those from equatorial regions are carriers of warmth; those from polar regions are reducers of heat.

GULF WEED.

9. Sargasso Seas.—An interesting evidence of the circulation of the oceanic waters is to be found in what are known as Sargasso Seas, so-called from *sargazo*, the Spanish name for seaweed. These are vast collections of drifting seaweed, which gather in those portions of the different oceans which are most free from the influence of currents.

If bits of cork or chips, or any floating substance, be put into a basin, and a circular motion be given to the water, all the light substances will be found crowding together near the centre of the pool where there is the least motion. Like such a basin is the Atlantic Ocean, with its Equatorial Current, and its Gulf Stream. The Sargasso Sea is at the centre of the whirl.

The Sargasso Sea of the Atlantic embraces an area of several hundred thousand square miles; and though the weeds are all afloat and held by nothing, yet the Sargasso remains where it was nearly 400 years ago, when Columbus passed through it on his first voyage to America.

During the author's researches connected with the "Physical Geography of the Sea," the existence of four other Sargassos was established, viz.: one in the Indian Ocean, two in the Pacific, and another in the Atlantic. [See Chart, pp. 62, 63.]

TOPICAL ANALYSIS.

VIII. CURRENTS OF THE SEA.

1. **Currents of the Sea.**
   Magnitude. Temperature. Classification. Direction, how modified. Trend of polar and return currents. Mode of naming currents.
2. **Currents of the Atlantic.**
   The Equatorial Current. Point of division. Brazil Current. The Gulf Stream. Dimensions. Temperature. Color. Offices. Polar currents, north and south.
3. **Currents of the Pacific.**
   General character. Australian Current. Kuro Siwo or Black Stream. Polar currents. Humboldt Current.
4. **Currents of the Indian Ocean.**
5. **Counter Currents.**
6. **Oceanic Circulation.**
7. **Causes of Oceanic Circulation.**
   Chief cause. General law. Causes of changes in specific gravity. Effects of heat and cold. Of evaporation. Of precipitation. Illustrations from the Red, Mediterranean and Baltic Seas. Effect of salts in promoting changes of specific gravity. Effect of formation of coral-reefs. Winds a cause of currents. Effect of Trade Winds. Of monsoons. Of storms.
8. **Office of Ocean Currents.**
9. **Sargasso Seas.**
   Description. Cause. Number and location.

Test Questions.—Which of the currents of the sea exerts the most important influence on climate? Why? General effect of oceanic currents on climate? Effect of saltness of the sea? Influence on commerce? Are the currents of the sea of any benefit to marine animals? Who discovered the first known Sargasso Sea?

TOPICAL ANALYSIS FOR REVIEW.

- **Properties of Water.**
  - Composition.
  - Changes of form. Uses in the solid and gaseous forms.
  - Expansion in freezing. Important result.
  - Capacity for heat.
    - Heat rendered latent in melting. In evaporation.
    - Effect on climate.
  - Solvent power.
  - Circulation between sea and land.
- **Waters of the Land.**
  - Springs. How caused. Remarkable kinds.
  - Rivers.
    - How formed. River-systems. Cataracts. Offices of rivers.
    - How rivers change surface of the earth.
      - Erosion. Cause. Effects.
      - Transportation.
        - Power.
        - Quantity of matter.
      - Deposit
        - Causes.
        - Results.
          - Deflection of current.
          - Bars.
          - Deltas.
          - Branching of rivers.
    - Relation to ocean life.
  - Lakes.
    - Formation. Cause of overflow. Salt lakes. Inland seas.
    - Offices.
    - Distribution.
- **Drainage**
  - Advantages.
  - How effected
    - Quantity of water delivered by rivers.
    - Cause of inundations. Examples.
- **Continental Drainage.**
  - North America.
  - South America.
  - Europe.
  - Asia.
  - Africa.
  - Australia.
- **The Sea.**
  - Extent. Relative area in northern and southern hemispheres.
  - Saltness.
    - Saline ingredients. Quantity.
    - Variation with distance from and at the equator.
  - Origin of saltness.
  - Color.
  - Phosphorescence.
  - Temperature. Variation with depth, place and season.
  - Offices.
- **The Oceans.**
  - The oceans
    - Number.
    - Form of basin.
  - Depth
    - The Atlantic.
    - The Pacific.
  - Bottom
    - General form.
    - Beds of explored oceans.
- **Waves and Tides**
  - Waves
    - How caused.
    - Nature of wave-motion. Height. Velocity.
    - Force and work of waves.
  - Tides
    - General description.
    - Theory of tides. High. Low. Spring and neap.
    - Origin of tidal wave. Movement in different oceans. Co-tidal lines.
    - Speed of tidal-wave.
    - Height of tides in different localities. Charybdis and the Maelstrom.
    - Tides of rivers. Bores.
- **Currents of the Sea.**
  - Currents in general
    - Magnitude. Temperature. Classification.
    - Direction. How modified. Rotation.
    - Mode of naming.
  - Currents of the Atlantic.
    - Equatorial Current. Brazil Current.
    - Gulf Stream. Polar currents.
  - Pacific currents
    - General character. Australian Current.
    - Japan Current. Polar currents.
  - Currents of the Indian Ocean.
  - Causes of oceanic circulation.
    - Chief cause. General law.
    - Causes of changes in specific gravity.
    - Effect of salts on circulation.
    - Winds a cause of currents. Office of ocean currents.
  - The Sargasso seas.

PART IV.

THE ATMOSPHERE.

I. PHYSICAL PROPERTIES OF THE ATMOSPHERE.

1. The Atmosphere.—Wherever we go on the surface of the earth we perceive that air is present. If we ascend above the mountain tops, or pierce the loftiest clouds, it is still with us. It envelops the earth.

The entire mass of the air is commonly spoken of as the *atmosphere.* Its upper portion, which on a clear day is blue, we call the sky.

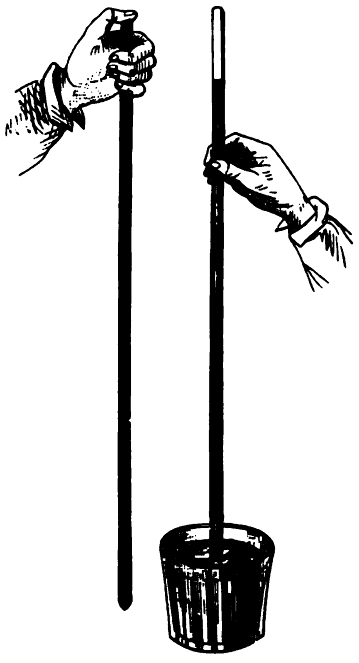
COMPOSITION.—The first question which naturally occurs to us regarding the air is, What is it? It was long thought to be an element, *i.e.*, something unmixed with anything. else. About one hundred years ago it was found to consist mainly of two gases. Names had to be invented for them. They were called Oxygen and Nitrogen. In every one hundred gallons of air there are about seventy-eight of nitrogen and about twenty of oxygen. Vapor of water and carbonic acid gas are also present in the atmosphere. The latter consists of carbon combined with oxygen.

The vapor, besides its other offices, mitigates the fierceness of the solar rays by day, and prevents radiation into space, or the escape by night of certain portions of the heat that the earth receives from the sun during the day.

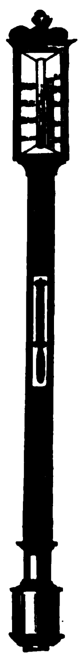
The plants, by means of their leaves, appropriate carbon from the carbonic acid. From it, and the water obtained through their roots, they elaborate fibre, fruits and flowers, returning the oxygen again to the air for the use of "everything that hath breath."

2. Weight of the Air.—As we do not feel ourselves pressed down by the air, it may seem surprising that it has weight. Yet, in truth, it is very heavy. The famous Galileo was the first to point this out. A pump-maker wished to know from him why a pump would not raise water from a well which was more than thirty-two feet deep. Galileo concluded that it was because a column of water thirty-two feet high is as much as the weight of the air can balance.

BAROMETER.—Torricelli, a celebrated pupil of Galileo, confirmed the conclusion of his master. He filled a tube, about three feet in length, with mercury. He then inverted the tube and placed the open mouth in a vessel of mercury. The mercury in the tube then fell, until it was about thirty inches in height. This column of mercury was sustained by the weight of the air. Torricelli thus discovered what is known as the *barometer* or weight-measure, (from the Greek *baros*, weight, and *metron*, measure).



TORRICELLI'S EXPERIMENT.



BAROMETER.

Pascal, a French philosopher, completed the work of Galileo and Torricelli. He argued that if the atmosphere has weight, that weight must be less on the top of a mountain than down at the base, and that, consequently, a less column will be sustained above than below. The experiment was tried upon the Puy de Dôme, a lofty mountain in France. It established the fact that the air has weight; for the mercury fell about $\frac{1}{10}$ inch for every ascent of about ninety feet.

The weight of the atmosphere is commonly called its pressure.

AMOUNT OF PRESSURE.—At the level of the sea the atmosphere presses with the weight of fifteen pounds* upon every square inch. Although its pressure upon the body of each one of us is several thousand pounds, yet, in consequence of the simple law of nature, that the atmosphere presses equally in all directions, we do not feel it.

An interesting consequence of the weight of the atmosphere is the fact that the boiling point is lowered at high elevations. At about the level of the sea, water boils at 212° Fahr. At Quito, 11,000 feet high, the boiling point is 194° Fahr. On the top of Mont Blanc, nearly 16,000 feet high, it is 180°.

This arises from the diminished pressure to which water is subjected at great elevations. It has the inconvenient effect of making it impossible in such situations to cook by boiling.

VARIATIONS IN PRESSURE.—Variations in atmospheric pressure are occasioned (1) by change of level; (2) by changes in the weight of the air.

Effect of Change of Level.—As you ascend a mountain, you pass through a certain proportion of the atmosphere, and are, of course, relieved from a portion of its pressure. For the first 10,000 feet of ascent the barometer falls ten inches; an average of one inch to every 1,000 feet of ascent. For the second 10,000 feet the barometer would fall about 6.7 inches, the amount of its fall constantly decreasing as you ascend. Mr. Glaisher in his balloon reached a height of 37,000 feet, and then the barometer went down to seven inches.

The lowest reading of the barometer ever observed upon a mountain was 13.3 inches, at an elevation of 22,079 feet, on the summit of Ibi-Gamin, in Thibet. It is easy to see that the amount of fall furnishes a means of measuring heights of mountains, and altitudes to which balloons ascend.

Effect of Changes in Weight of the Atmosphere.—A fall of barometer occurs, also, when the column of air above any area becomes lighter than usual. This takes place when there is more than the ordinary amount of vapor in the air; because vapor is lighter than dry air. Consequently, the greater the proportion of vapor in the air, the lighter that air will be. A *low barometer* therefore usually indicates a moist, rainy atmosphere. A *high barometer* indicates that the atmosphere is heavy; either because it is dry, or because it is dense.

HEIGHT OF ATMOSPHERE.—The main body of the atmosphere is about forty miles high. I
probably extends in a state of extreme attenuatio
to the height of several hundred miles.

THE DENSITY, or compactness of the air, o
course diminishes with the height. On loft
mountains it is highly rarefied, which means tha
its particles, being relieved from pressure, ar
more widely separated from one another than a
lower levels.

Persons ascending to great elevations sometimes expe
rience a singular difficulty. The walls of the blood-vessel
burst, and there is a flow of blood from the nose and ear
This *mal de montagne* is seldom felt at a lower level tha
16,000 feet, and balloon ascents have been made to a heigh
of 29,000 feet before any serious inconvenience has arise
from this cause.

TOPICAL ANALYSIS.

I. PHYSICAL PROPERTIES OF THE ATMOSPHERE.

1. The Atmosphere.

Composition. Uses of the vapor of water and ca
bonic acid.

2. Weight of the Air.

Evidence that the air has weight from the action
the common pump. From Torricelli's experimen
From Pascal's experiment.

Amount of pressure. Effect of pressure on th
boiling point. Variations in pressure, to wh
due. Effect of change of level. Lowest barome
ric readings observed. Effect of change in th
weight of the air. Meaning of high and lo
barometer. Height of the atmosphere. Variatio
of density with height. Physiological effect.

TEST QUESTIONS.—What is the color of the atmosphere? Of wh
use is this to us? A cubic yard of air weighs about 2.2 lbs: what is t
weight of the air in a room 15 feet square and 12 feet high? Have y
ever observed anything to indicate that the air has weight? How lo
ago did Galileo live? Above the mercury in the barometer is
vacant space called the Torricellian vacuum: why should it be
called?

II. CLIMATE.

1. Main Elements.—The temperature an
moisture of the air are the two main elements
climate. Obviously the more important of thes
is temperature.

The principal causes which modify temperatu
are, distance from the Equator; distance from th
sea; prevailing winds and ocean currents; an
height above the sea-level.

2. Distance from the Equator.—Th
first and most apparent cause of difference of cl
mate is distance from the Equator. This
results: (1) as the distance increases
annual temperature falls; and (2)
and greater contrasts of summer
cold.

EFFECT ON ANNUAL T

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[*] This may be verified by the simple experiment of employing a barometric tube one square inch in bore. A column of mercury thirty inches high in such a tube weighs fifteen pounds.

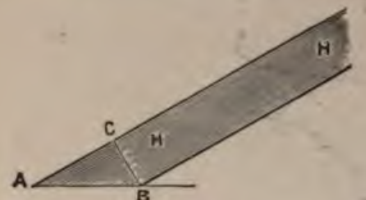
within the tropics receives the vertical rays of the sun, and is therefore the region of greatest heat.

Between the tropics and the polar circles the sun's rays fall slantingly, and exert therefore a feebler power.

Within the polar circles the slant of the sun's rays is at its greatest, and hence, except during a brief period of a few weeks, excessive cold prevails.

The reason why less heat is received where the sun's rays are oblique may be readily understood from the accompanying diagram.

If the beam of heat, HH', fall vertically, it will be distributed over a smaller space (CB) than if it falls obliquely. The amount of heat, therefore, received at any point along AB is diminished in the same ratio as the surface is increased. The intensity, therefore, of the heat upon the surface AB is to its intensity upon CB, inversely as the surfaces, or as CB is to AB.



SUN'S RAYS.

Climatic Contrasts.—The contrasts between summer heat and winter cold are mainly due to variations in the length of the day, and these depend on distance from the Equator.

Within the tropics there is comparatively little difference between the two periods of day and night all through the year.

Only twice in the year, at the equinoxes, are they equal for other parts of the globe.

As the sun passes northward from the Equator, the day lengthens all over the northern hemisphere, until, within the Arctic circle, the sun does not set at midsummer at all. The same thing occurs for the southern hemisphere, after the sun passes southward of the Equator.

Now it is because there is very little difference between day and night at the Equator that we find within the tropics a nearly uniform temperature throughout the year.

And it is because north and south of the tropics there are important differences between day and night, that in all regions outside of the tropics climatic contrasts are found.

At the poles these contrasts are at their maximum. The summer of the polar regions, strange to say, is exceedingly hot.* It is marked by a ra[illegible]ity of vegetable growth that is marvellous. In a few weeks crops mature which require twice that length of time in latitudes much nearer the Equator. But, on the other hand, the winter cold is correspondingly excessive.

Explanation.—We shall better understand the climatic effects of variations in the length of day and night, if we know something about the absorption and radiation of heat.

If two bodies are of different temperatures, heat will pass through the space between them from the warmer to the cooler. The giving off of heat by the warmer body is called *radiation*. The receiving of it by the cooler is called *absorption*.

If a red-hot cannon-ball be placed near a mass of ice, heat will be radiated from the cannon-ball to the ice. The ice will absorb the heat from the ball. So wherever the sun is shining, the earth is absorbing heat. Wherever it is night-time, the earth is radiating heat into the cooler regions of space.

It is clear that when the day-time of northern regions is lengthened, the quantity of heat absorbed is greater; and, at the same time, since the nights are shorter, the loss of heat by radiation is less. Hence, there is every day an accumulation of heat.

It is for this reason that our own hottest weather occurs subsequently to the longest day, and that in places like St. Petersburg and Yakutsk, where the sun is below the horizon at midsummer only for about three hours, the summer heat is intense.

3. *Distance from the Sea.*—In certain countries climate is affected more by distance from the sea than by distance from the Equator.

The climate of a region adjacent to the sea is called an *insular* or *maritime* climate. The climate of a region remote from the sea is called an *inland* or *continental* climate.

Insular Climates.—Certain causes moderate insular climates.

(1) Water absorbs heat much more slowly than the land, and therefore remains, in hot weather, comparatively cooler. Hence the summer temperature of a country bordering on the sea is lowered.

(2) On the other hand, water parts with its heat by radiation much more slowly than the land, and therefore remains in cold weather comparatively warmer. Hence the winter of a maritime country is moderated.

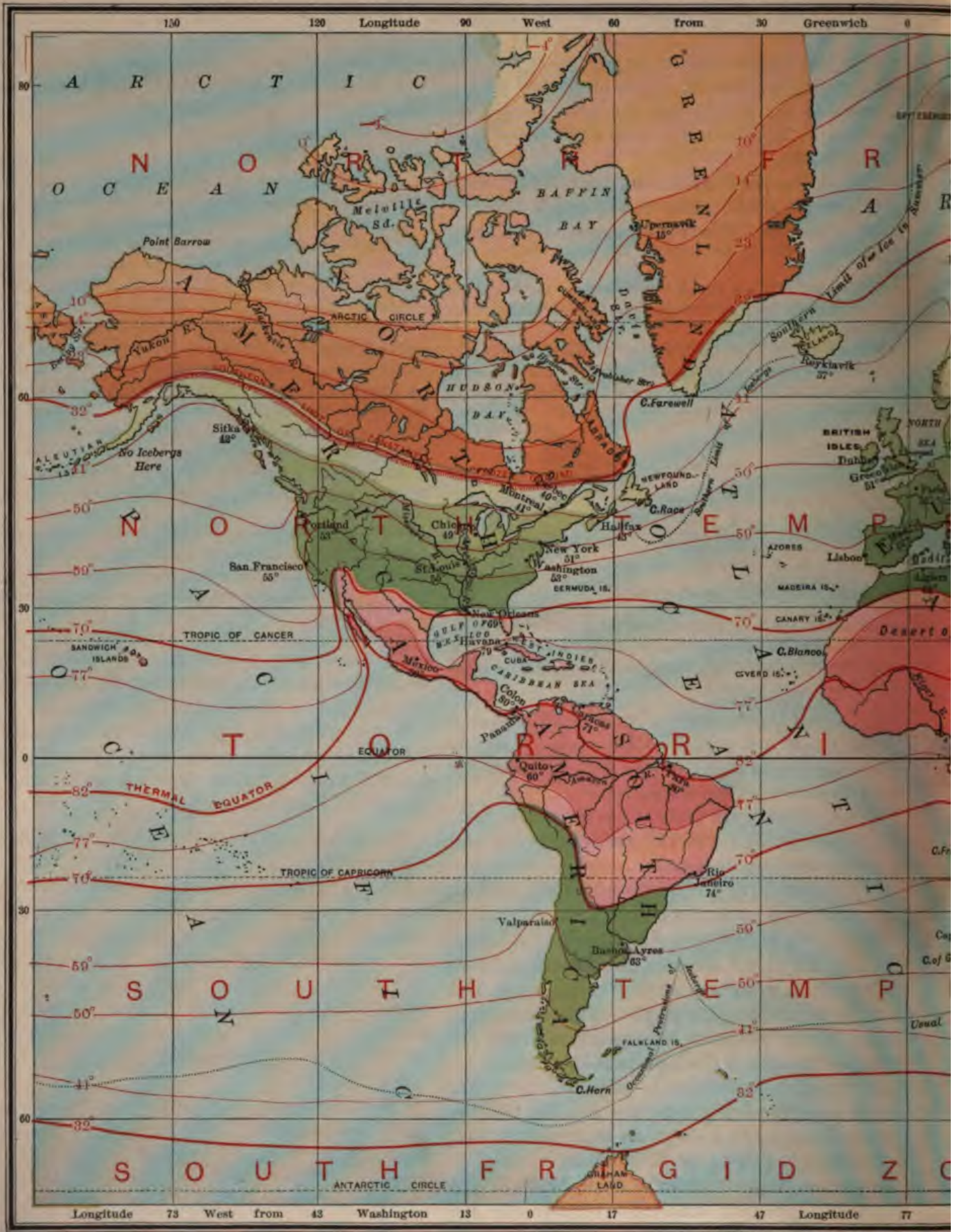
(3) Vapor is incessantly rising from the sea, and, being condensed, falls as rain or snow upon the land, and, as you have learned, this liberates latent heat.

(4) The vapor in the atmosphere of a maritime climate prevents the escape of heat. It acts like a warm blanket. A familiar illustration of this is the fact that we rarely have frost on cloudy nights.

(5) But again, since the process of evaporation goes on more rapidly in hot weather than in cold, it has the effect of moderating the summer heat of a maritime country.

For the above reasons, ***insular or maritime climates are equable, or free from extremes.***

[illegible] of the Arctic circle, the tempera[illegible] in summer.



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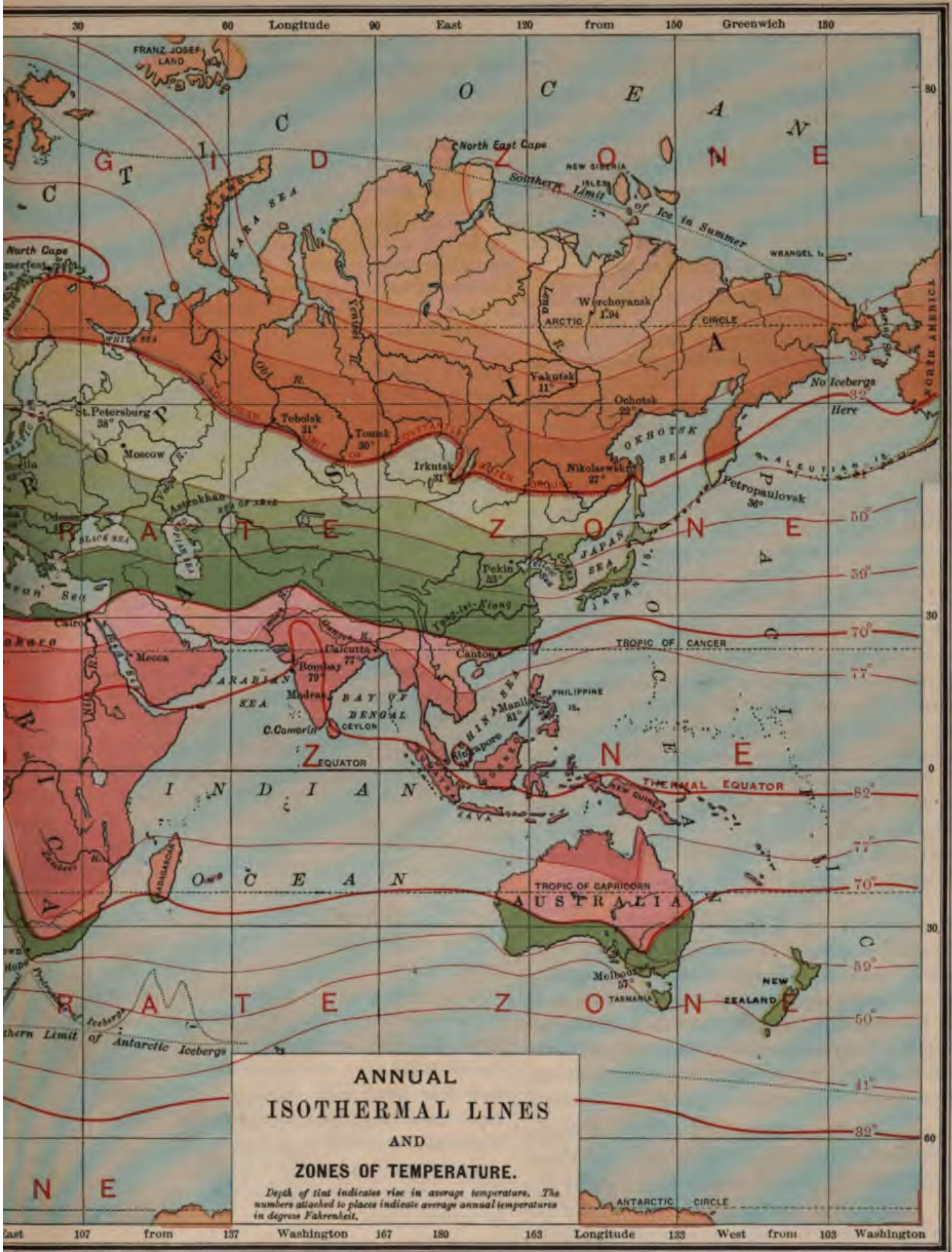
QUESTIONS ON THE ISOTHERMAL CHART.

What are isothermal lines? Why should the isotherms be so irregular and differ so much from the parallels of latitude?

New York and Rome are in about the same latitude; how do their mean temperatures compare? The same isotherm passes near New York and London; how much difference is there in the latitude of these two cities?

Trace the course of the Thermal Equator. What is the average annual temperature of places through which it passes? What isotherms bound the zone of Tropical temperature? What isotherms bound the Temperate zones? The Polar? Through what coun-



ANNUAL

ISOTHERMAL LINES

AND

ZONES OF TEMPERATURE.

Depth of tint indicates rise in average temperature. The numbers attached to places indicate average annual temperatures in degrees Fahrenheit.

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tries of each continent does the isotherm of 32° pass?

North of this line what is the condition of the ground? In which continent is the "limit of constantly frozen ground" farthest to the north? On which side of our continent is it farther north? What difference between the annual temperature of Labrador and the British Isles?

What parts of North and South America have the same annual temperature as Italy and Spain? What parts of Europe have the same annual temperature as Alaska?

What should you judge from the chart to be the annual mean temperature of Mobile? Of Rio de Janeiro? Of St. Louis? Of Charleston? Of Buenos Ayres? Of Paris?

Explain the curving of the isotherms on the eastern and western coasts of South America.

INLAND CLIMATES.—*Inland or continental climates are the opposite of maritime. They are subject to great extremes, intense heat in summer and excessive cold in winter.*

Two reasons may be assigned for this:

(1) Countries far from the sea are without its cooling influence upon their summer heat, and they have no reservoir of warmth to compensate for their rapid radiation of heat in winter.

The continent of Asia affords the most striking instances of the excessive character of inland climates. The Russian army advancing towards Khiva in 1839–40 experienced vicissitudes of temperature from a heat of over 100° Fahr. to a cold of 45° below zero.

At Werchojansk, Eastern Siberia, the culminating point of excessive climate in all the world is reached. The extreme temperature of 90.4° below zero Fahr. has been observed there. This is far below the average of the polar ocean. The soil is permanently frozen to the depth of 380 feet. In the month of June the Lena is free from ice; the surface soil has thawed for 3 or 4 feet; and the warmth of the short summer is such that grain will ripen in the shallow stratum of soil above the frozen mass. The mean temperature of July at Yakutsk is 69° Fahr., the same as at Paris.

(2) The comparative dryness of the air of an inland region contributes to create extremes. This is strikingly illustrated by the climate of the Sahara. The air there is perfectly dry. No vapor hinders the reception of heat by day or its loss by night. By day the sand is as fire and the wind like flame; and yet the temperature may fall from 200° Fahr. during the day to freezing-point during the night.

Travellers have been known to find the water in their canteens turned into ice before morning.

4. Prevailing Winds and Ocean Currents.—The climate of a country is also greatly modified by the prevailing winds and the neighboring ocean currents. If the prevailing winds come from the sea, they temper the extremes of heat and cold. If a cold current bathes any portion of the shore, it lowers the temperature; a warm current raises it.

Examples.—The British Isles and the province of Labrador are the same distance from the Equator, and in many parts the same height above the sea. Yet such is the difference of climate between them, that Labrador is covered with snow for nine or ten months every year, and is so cold as to be almost uninhabitable; while in England the ground is rarely covered with snow, and the pastures are green all the winter.

Both countries are in the regions of westerly winds; but in Labrador they come from the land, and are dry and cold; in England they come from the sea, and are laden with moisture and warmth. The shores of Labrador are washed by a cold Arctic current; those of Great Britain by the warm waters of the Gulf Stream and Atlantic Drift.

The climates of Western Europe, from North Cape all the way down to the Straits of Gibraltar, are modified by the sea-winds and the influence of the Gulf Stream and Drift.

Norway stretches up beyond the 70th degree of north latitude; yet the westerly winds are so richly laden with warmth and moisture from the waters of the Gulf Stream that the harbor of Hammerfest, lat. 70° 40′, is never frozen, even in the severest winters. But cross the Scandinavian mountains, and you encounter at once, if it be winter, the severest cold. In this short distance from the warm waters and the west winds of the Atlantic, you find the Russian lakes and rivers, the gulfs and bays of the Baltic, closed against navigation every year from November till May.

Climatic conditions similar to those which affect the western shores of Europe are found upon the western slopes of Oregon, British Columbia, and Alaska. Westerly winds prevail, and they are laden with moisture from the Pacific Ocean. The result is that here, as in Norway, open harbors and evergreen hills are found in the high latitudes of Alaska and other parts of our northwest coast.

5. Height above the Sea-Level.—Among other circumstances, climate depends upon height above the sea. A change of elevation of a few thousand feet at the Equator produces a change of temperature as great as would be experienced in sailing 6,000 miles to the frozen regions of the poles. [See small map p. 105.]

The Island of Cuba and the Mexican mountain of Orizaba are in the same latitude. The summit of the mountain is covered with snow all the year; the island with fruits, flowers, and evergreens.

The reason why elevation above the sea-level causes reduction of temperature is that the radiation of heat goes on from elevated parts of the earth's surface more freely than from its lower portions. Two causes may be assigned for this: (1) elevations are comparatively small, and therefore lose heat with rapidity; (2) the air and vapor upon elevations are rarefied, and hence little hindrance to radiation is presented.

The general rule as to the effect of elevation is this: *for every one hundred yards of perpendicular ascent there is a decrease of one degree in the temperature;* so that, even at the Equator, you may, by ascending to the height of about sixteen thousand feet above the sea, reach the snow-line, where the cold is extreme and the winter eternal.

6. Isothermal Lines.—From thermometric observations made in all parts of the world, the actual distribution of temperature over the globe has been ascertained. To show this, Humboldt constructed a series of lines called *isothermals* or *lines of equal heat.* These are drawn round the globe so as to connect all places which have the same mean temperature during the year or any given part of the year.

Isothermal lines are far from coinciding with the parallels of latitude. Let us take by way of illustration the line in the Northern Hemisphere indicating the mean annual temperatute of 50° Fahr. [See chart pp. 72, 73.] It passes through Oregon on the Pacific shores, and leaves our Atlantic coast between New York and New Haven. It bends northward in crossing the Atlantic, and in Europe passes through Liverpool, Vienna, and Odessa, and in Asia, near Peking.

We are not to conclude, however, that because the same isothermal line passes through two places, they have a climate identically the same. Of two such places one may have an extremely hot summer and a correspondingly cold winter. The other may have a climate free from extremes. Yet both may have the same average yearly temperature.

Thus San Francisco and Washington have the same mean annual temperature, while their climates are very different.

Again, the same isothermal line passes through New York and Dublin. Yet the climates of these places have no resemblance. The mean winter temperature of Dublin is six degrees above that of New York; while the summers of the two places are so unlike, that whereas grapes and Indian corn are successfully cultivated in the vicinity of New York, they will not ripen in the open air, at Dublin.

ZONES OF TEMPERATURE.—By means of isotherms we define the zones of temperature. They are indicated by the colors on the chart. The true *Torrid Zone* is bounded by the isotherms of 70° on either side of the Equator. The true *Temperate Zones* extend from the isotherms of 70° to those of 32°. The *Frigid Zones* extend from these to the poles.

TOPICAL ANALYSIS.

II. CLIMATE.

- **1. Main Elements.**
  - Causes which modify climate.
- **2. Distance from the Equator.**
  - Results of distance from the Equator. Effect on annual temperature. Climatic contrasts. Explanation.
- **3. Distance from the Sea.**
  - Insular and inland climates. Causes which moderate insular climates. Reasons for the extremes of inland climates.
- **4. Prevailing Winds and Ocean Currents.**
  - Illustrations.
- **5. Height above the Sea-level.**
  - Effect of elevation. Cause of increase of cold with elevation. General rule.
- **6. Isothermal lines.**
  - Represent what. Relation to parallels. Zones of temperature.

TEST QUESTIONS.—How do the regions deficient in moisture compare in extent with those deficient in temperature? How would increase of moisture affect the temperature of desert regions? How can ocean currents affect climates as far inland as they do? In what climates have nations been most prosperous? If the climate of England should become a very dry one, how would that affect the temperature?

III. WINDS AND CIRCULATION OF THE AIR.

1. Air in Motion.—The ocean of air, like the ocean of water, is never at rest. It has its waves and its currents.

ANEMOMETER.

*A body of air in motion is called wind.** As we all know very well, the wind travels at various rates and in many different directions. By means of an instrument called the *anemometer*, it has been ascertained that the velocity of a light wind is five miles an hour; of a "stiff breeze," 25 miles; of a storm, 50, and of a hurricane from 80 to 100, or even 150.

Again: the direction in which a wind blows is so constantly changing that we often speak of the winds as fickle, inconstant and uncertain. There is, however, *order in the movements of the atmosphere.* The fickle winds are obedient to laws.

There are causes which make them blow with greater or less rapidity. There are reasons why they blow now north or south, now east or west.

2. Causes of Winds.—The main causes of winds are two: (1) the unequal distribution of heat in the atmosphere; and (2) the unequal distribution of vapor in the atmosphere.

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* Winds are named according to the quarter from which they blow. A *west wind* comes from the west, an *east wind* from the east.

EFFECT OF HEAT.—Let us consider the effect of the unequal distribution of heat in the atmosphere. If a fire be lighted on the hearth, the air in the chimney will be heated and forced up the chimney by an indraught of cooler and heavier air from all parts of the room. This continues as long as the fire burns.

The same thing occurs when a bonfire is lit, or a house is on fire. Every child knows that "the sparks fly upward to the sky." They are carried up by the hot ascending current. The air above the fire is expanded, rendered lighter, and driven upward by currents of cool air that come rushing in from all sides. These, when heated, ascend with such force as to carry up clouds of smoke and sparks.

This unequal distribution of heat, the warming of the air in the chimney or above the burning house, while that in the room or in the space about the burning house is comparatively cold, *establishes a system of air currents.*

If there are no obstacles in the way of these currents, and if they are not chilled or heated in their course, they will go straight toward the mouth of the chimney. Chairs and tables and other objects in the room will deflect them and cause more or less irregularity in their direction.

To prove that such currents really do flow, place a lighted candle in the doorway of a room in which a fire is burning. You will see the flame drawn inward by the inflowing current.

Now what occurs in the air of a room when a fire is kindled on the hearth takes place in the atmosphere. Some portions of it are always more heated than others; and the unequal distribution of heat establishes a system of currents. The heated surface of the earth warms the air above it. This air, forced up by the surrounding cool air, ascends as a current; and streams of cooler, heavier air flow in. Just in proportion to the size of the area heated, the volume of the inflowing currents will be greater or less, and in proportion to the difference of temperature between the heated air and the inflowing currents, the rapidity of their flow will be greater or less.

EFFECT OF MOISTURE.—The effect of unequal distribution of moisture is similar to that of unequal distribution of heat. Vapor of water is only about half as heavy as dry air at the same temperature. Evidently, therefore, if there is much vapor in any part of the atmosphere, that part will become lighter than the neighboring portions. Like the air heated by the fire, it will be forced upward as an ascending current, and there will be an inrush of drier, heavier air to supply its place.

In general, the two causes above mentioned operate together, for it is natural that where there is most heat, there is also most vapor present in the atmosphere. For this reason, and because the effect of the two is so similar, it will not be necessary to consider in detail the effect of vapor as a cause of air-currents.

3. General Circulation of the Atmosphere.

—Let us now turn our attention from these simple illustrations to what is going on in the atmosphere at large.

Within the tropics there is perpetual summer. The vertical rays of the sun are incessantly heating the torrid zone and its atmosphere, and filling the air with vapor, while the air on either side of that zone is comparatively dry and cold. What must be the effect of this *unequal distribution of heat and vapor?* It *creates a general circulation of the atmosphere.*

In the first place, as in the case of the fire upon the hearth, the heated, moist air of the tropics is pressed upon by the heavier air on either side. It is forced upward, and there is an indraught both from the north and the south to supply its place.

Now, if the earth were at rest, and if its surface were covered with water, the inflowing currents would go straight from the polar to the equatorial regions. There would then be a simple circulation of light air from the equator to the poles, and of heavy air from the poles to the equator. The winds would be steady and unvarying.

MODIFYING CAUSES.—But the earth is not at rest, and its surface, instead of being uniformly covered with water, is varied by land masses of greater or less magnitude and elevation. The rotation of the earth and the influence of its land masses are two causes which largely affect the circulation of the air, and render it exceedingly complicated.

WINDS ARE CLASSIFIED, according to the regularity with which they blow, as *constant, variable,* and *periodical.*

4. Constant or Trade Winds.

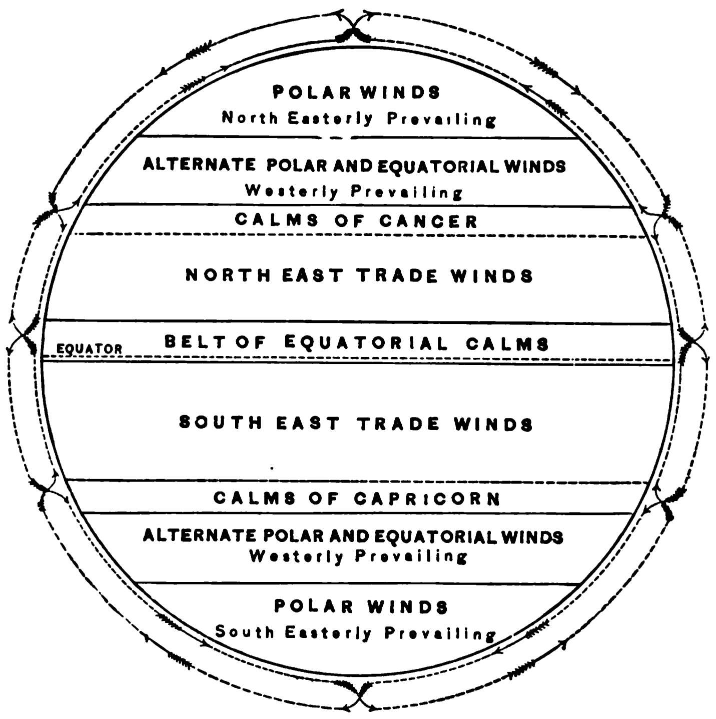
—Certain of the winds blow without interruption in the same direction, and at nearly the same rate. So constant are they that vessels often sail in them for days and days without, as the sailors say, "changing a stitch of canvas." It was the steady blowing of these winds which so alarmed the crew of Columbus on his first voyage to America, and led them to fear that they should never get back to Europe.

From their importance to the navigator these winds have been called the *trade winds* or *trades.* They are currents of air which are ceaselessly winging their flight from the polar and temperate regions toward the equator.

Direction.—If the earth had no daily motion, these winds would blow on one side of the equator from the north, on the other from the south, directly into the equatorial regions. But in consequence of diurnal rotation, the air, when it arrives at the equator, is in a region which is moving toward the east, 120 miles an hour faster than the region in latitude 30°, where it began to blow as a trade wind.

During its whole journey to the equator the wind lags a little behind, and the earth, which is revolving from west to east, is slipping from under it all the time, so that the wind appears to come from the east. Thus an additional motion is imparted to it—viz., a motion toward the west; and so it is made to come from the northward and eastward on the north side, instead of directly from the north; and from the southward and eastward on the south side, instead of directly from the south.

Thus we have the *two systems of trades;* the *northeast* and the *southeast*. The northeast trades blow from about the parallel of 30° north, to the equator; the southeast trades from about the parallel of 30° south, nearly to the equator. Both extend entirely round the world.



CIRCULATION OF THE ATMOSPHERE.

Diagram showing course of currents of air from the equator to the poles and back. Let the pupils all draw from memory similar diagrams.

5. *Variable Winds*.—North and south of the trades are the zones of the variable winds. They extend from the parallels of 30° north and south, to the polar circles. Within these limits the winds blow without regularity. Two systems contend, and sometimes the one prevails, sometimes the other. These contending winds are the counter trades, which blow from the equator, and the polar winds, which blow from the poles. The variable winds are designated on the chart, p. 79, as polar and equatorial winds.

Counter Trades.—Referring to the chart, you see that on the polar side of the trade winds, the arrows show that the prevailing direction of the winds is *counter* or opposite to that of the trades—that is, from the southward and westward in the northern, and from the northward and westward in the southern hemisphere. For this reason these westerly winds are called the *counter trades.*

Origin.—The origin of these winds is interesting. It is thus explained. While the trades blow steadily from the poles, there must be return-currents from the equator to the poles, otherwise the polar regions in time would be destitute of air. When the upward current at the equator has risen to a considerable elevation above the surface of the earth, it divides and flows toward the poles, one volume going toward the north, the other toward the south pole.

These two streams of air remain upper currents as far as the northern and southern limits of the trade winds—*i. e.*, about as far as the parallels of 30° north and south.

When, however, they have gone so far on their northward and southward journey, they descend to the surface of the earth, probably for the reason that their temperature has fallen below that of the air which is flowing from the poles. They now flow as surface winds and constitute the counter trades.

Proofs.—That the upper currents above alluded to do flow out northward and southward from the equatorial regions is abundantly proved. Sometimes volcanoes, as we have already learned, eject vast quantities of dust. Not unfrequently this passes into very elevated regions of the atmosphere; and instances are on record of its being carried sometimes for hundreds of miles in a direction opposite to that of the surface winds.

Coseguina, in Guatemala, is in the region of the northeast trades. During the eruption of 1835, its ashes were carried to the island of Jamaica. Jamaica is 800 miles northeastward of Coseguina. No other explanation of this

is possible, except that an upper current was blowing above the surface winds, in a direction opposite to theirs.

Again, in 1815, ashes from a volcano in the island of Sumbawa, near Java, were borne to the island of Amboyna, 800 miles to the northeast, although the southeast wind was then at its height. This again proves that there must have been a powerful current toward the northeast, above the southeast surface-wind. It is clear, therefore, that return currents flow from the equator to the poles, as indicated on the chart. We shall see in the following paragraphs what becomes of these return currents.

Direction.—Were it not for the earth's rotation, the counter trades would move straight to the poles. But rotation has upon them a similar effect to that which it has upon the trades. It changes their direction, and it gives them motion from the westward. This is explained as follows: while in the equatorial regions, these winds have acquired the rapid rotary motion toward the east which belongs to those regions. Hence, when they reach latitudes nearer the poles, they are blowing to the eastward with a velocity far more rapid than that which belongs to the latitudes which they have reached, and thus they become westerly winds.

THE POLAR WINDS are currents of cold air making their way from the poles toward the equator. Their direction is similar to that of the trade winds, northeast in the northern hemisphere, and southeast in the southern hemisphere. Coming from the equator, the counter trades bring moisture and warmth; the polar winds are dry and cold.

The trades, counter trades and polar winds, though treated separately, are really only parts of the same great atmospheric current which is ceaselessly accomplishing its unending circuit from the equator to the poles, and from the poles back to the equator, as shown in diagram on p. 77.

6. The Calm Belts.—When two equal currents of air meet, a calm is produced. Over the equator, where the northeast and southeast trade winds meet, there is a belt of calms encircling the earth. It is called the *Equatorial Calm Belt.* This name is not altogether a good one, because throughout the belt a vast current of air is incessantly ascending. The belt is calm in the sense of being comparatively free from horizontal movements of the atmosphere.

The most difficult part of the ocean for sailing-vessels to cross is this calm belt. Ships are sometimes detained here for many days.

As where the northeast and southeast trade winds meet, so where the trades and counter trades meet and cross, there is, in each hemisphere, a belt of atmosphere marked by the prevalence of calms. In the northern hemisphere we have the *Calms of Cancer;* and in the southern the *Calms of Capricorn.*

The *position* of all the calm and wind b above described is not invariably fixed. *They move northward and southward, following the parent march of the sun.* They reach their farth northward limit in autumn, their farthest sou ern limit in spring.

7. The Periodical Winds are those wh blow for a certain time in one direction, and t for an equal, or nearly equal time, in the oppo direction. They are the *land* and ***sea breezes,*** the *monsoons.*

LAND AND SEA BREEZES.—All along the shore of warm countries, there is a breeze fr the sea by day, and one from the land by nig The rays of the sun heat the land more read than they do the water. This makes the la warm in the day, leaving the sea cool; the wa rocks, sand, and soil, heat and expand the air contact with them and render it light. Pres upward by the cooler air of the sea, it rises. C rents then come rushing in from the sea to sup the place of the ascending columns, precisely the indraught to a furnace supplies the rush the chimney: thus we have the ***sea-breeze.***

By night the opposite effect occurs. The la has the property of radiating—that is, of throwi off—its heat more rapidly than the water c Hence the land by night grows cooler than sea. It then cools and makes heavier the above it. The air above the sea remains compa tively warm and light. Hence it is pressed ward by the cooler air of the land, and curre rush from the land to the sea. This is the *la* ***breeze.***

QUESTIONS ON CHART OF WINDS.—(The red color on chart indicates the constant or trade winds; green, variable winds, or those which blow alternately from equator and the pole; blue, the northeasterly winds bl ing from the pole; yellow, the monsoons.)

Define the region of the trades. What do we find al their line of meeting? Where else do calms prevail? W special names are applied to the calms? Are the calms all seasons exactly where shown on the chart? Why no

Where do the great monsoons blow? Within the reg of what winds? Point out other monsoon regions.

How many regions of typhoons and hurricanes do find on the chart? Where are they? Describe the cou of the West India hurricanes. Of the Australian.

What is the direction of storms in the regions nort the equator? In those south of the equator?

What winds occasionally prevail in Northern Africa? the countries of Southern Europe? Where do these la come from? Where does the Harmattan of Guinea c from?

Trace the circulation of a volume of air, sup start northward from the equator. Supposi southward. (See diagram p. 77.)

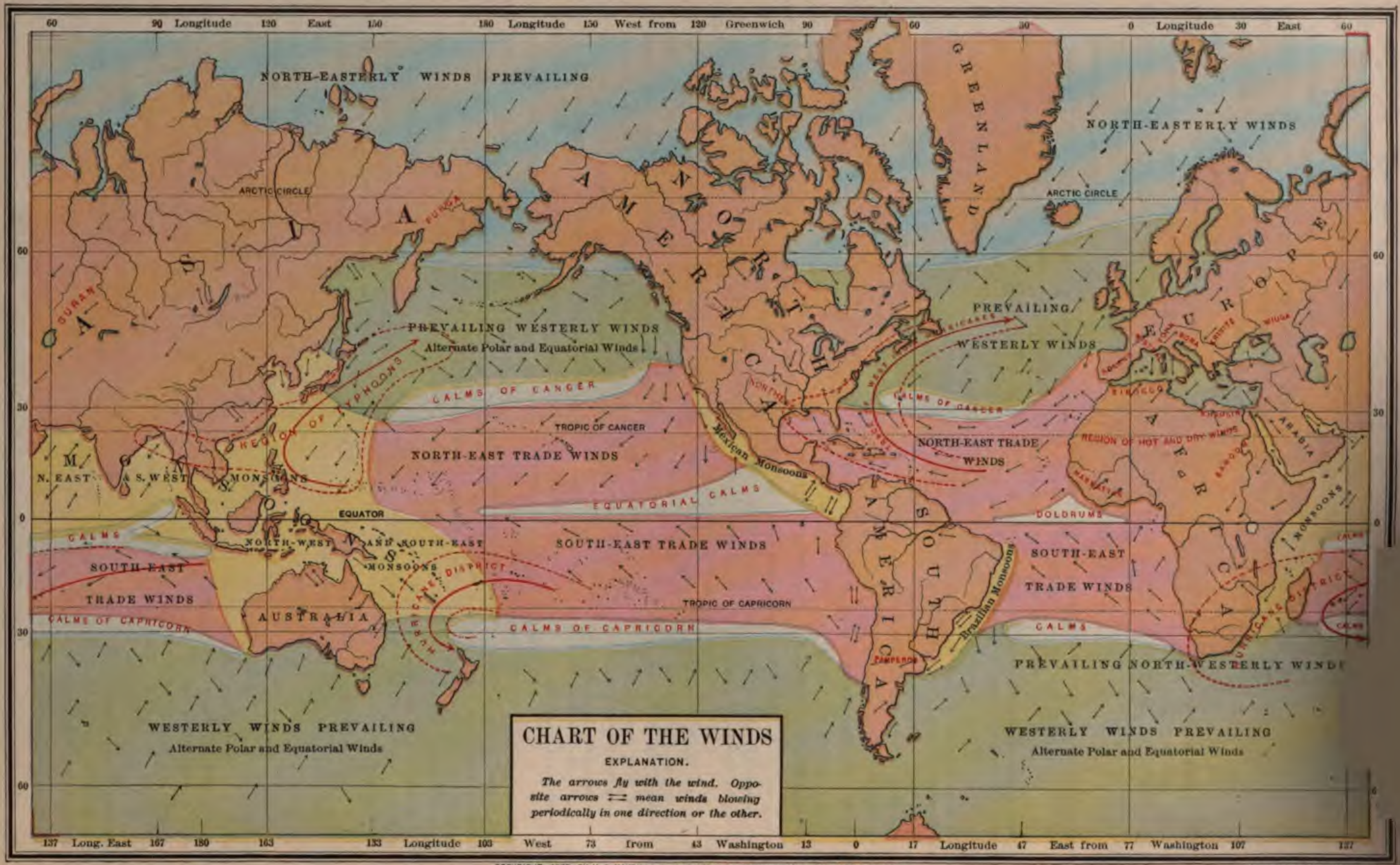


CHART OF THE WINDS

EXPLANATION.

The arrows fly with the wind. Opposite arrows ⇄ mean winds blowing periodically in one direction or the other.

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Were it not for these refreshing breezes, many countries along the sea-shore, that are now the abodes of health, prosperity and happiness, would be uninhabitable.

MONSOONS.—Monsoons are winds that blow from a certain direction for part of the year, and for the rest of the year from quite another quarter. They are land and sea breezes on a grand scale. Instead of alternating with day and night, they alternate with summer and winter. (Hence their name, from an Arabic word meaning *season.*)

The most famous monsoons are those of Southern Asia. In India they blow from the northeast for six months of the year, and from the southwest for six months.

Cause.—During the summer the sun plays upon the great deserts and inland basins of Central Asia. Those dry and barren wastes glow like furnaces, and the heated air ascends from them in immense columns. A disturbance is created which is felt to the distance of 2,000 or 3,000 miles from its centre. Cooler air rushes in from the sea on three sides of the continent. Along the coasts of Siberia it comes from the north. From China round the south of the continent to the Red Sea, it comes from the Pacific and Indian Oceans—that is, from the southeast, south, or southwest.

In this region, which is largely in the zone of "trades," the effect is so great as actually to reverse the trade wind and cause it to blow in the contrary direction.

In the winter the centre of Asia is a region of low temperature. Its atmosphere is dry, cold, and heavy. That of the seas surrounding the continent is moist, warm, and light. The light air is pressed upward by the heavy, and ascends into the upper regions of the atmosphere. Currents then blow from the land toward the sea. In consequence of this we have, during the winter in India, the northeast monsoons, which are really the northeast trades, blowing with augmented force and velocity; on the Chinese coast we have the northwest monsoons.

Effects.—The summer or the southeast and southwest monsoons having passed over the sea, are laden with moisture, and are the *wet* monsoons. They give its *wet* season to Southern Asia. The northeast and northwest monsoons are for the most part dry, because they come from the land. During their prevalence it is the *dry* season. The changing from the dry winds to the wet is called in India the "bursting" of the monsoon.

Bursting of the Monsoon.—The southwest monsoon sets generally toward the end of April, a steady wind sweeping from the Indian Ocean and carrying with it dense volumes of vapor. The atmosphere becomes close and oppressive. Flashes of lightning play from cloud to cloud. The wind suddenly springs up into a tempest. Then a few great heavy drops of rain fall; the forked lightning is changed to sheets of light, and suddenly the flood-gates of heaven are opened, and not rain, but sheets of water are poured forth, refreshing the parched earth, carrying fertility over the surface of the country, filling the wells and reservoirs, and replenishing the dwindling rivers and streams. The whole land from Cape Comorin to Bombay seems suddenly recalled to life.

MINOR MONSOONS.—Certain other winds that resemble the monsoons are those of Australia, the Gulf of Guinea, and the Mediterranean.

The winds of Australia blow landward in the hot months: seaward in the cold season. They are largely controlled by the great desert of Australia at the one season and by that of Gobi at the other. During the South Temperate summer the Australian desert is the hotter: during the South Temperate winter Gobi is the hotter. Each thus becomes in turn the controlling area.

The Australian monsoons, however, do not compare in regularity with those of India.

Over the Gulf of Guinea and the Mediterranean periodical winds blow in summer in opposite directions; the winds of the Gulf of Guinea come from the southwest, those of the Mediterranean—known to the ancient Greeks as the Etesian winds—are from the northeast. Both are due to one cause, viz., the intense heating of the Sahara. This produces an upward current of heated air and an inrush of cooler air from the Gulf of Guinea on the one side, and from the Mediterranean on the other.

The periodical winds of Mexico, Central America, and the Brazilian waters, and those known in Texas as "Northers," are due to causes similar to those of the monsoons.

OTHER PERIODIC WINDS of less importance are what we may call the return currents from the deserts. These are laden with heat, sand, and dust.

From the Sahara currents flow northward and southward. Those from the south enter Egypt, and blow for a few days at a time during a period of fifty days. Hence they are called *khamsin*, an Arabic word meaning fifty. During their prevalence the air is filled with blinding dust and the midday sun is darkened. By such a wind of unusual violence, the army of Cambyses, 50,000 in number, is said to have been destroyed, when on its way to attack the oasis and temple of Jupiter Ammon.

Crossing the Mediterranean, the desert wind scorches the vegetation of Southern Europe. It is known as the *sirocco.*

Mountain Winds.—The tops of mountains chill the surrounding air. This sometimes descends as a cold wind into the warmer regions below. Thus from the snowy heights of the Andes the cold *pamperos* sweep over the Pampas of the Rio Plata, the icy *puna* descends upon the table-land of Peru, and the chilling *mistral* descends from the Alps to the shores of the Mediterranean, causing infinite discomfort to sick and well.

8. Offices of Winds.—Three offices of winds may be mentioned: (1) they keep the elements of the atmosphere uniformly mixed by maintain-ing a constant circulation; (2) they bear vapor from the sea to the land, and thus water the earth; (3) they carry heat imprisoned in the particles of vapor, from the overheated regions of the earth to the colder ones, and in this way make the torrid regions cooler, and the temperate and polar warmer than they would otherwise be. Discharging these various offices, they verify the Psalmist's words, "God maketh the winds his messengers."

TOPICAL ANALYSIS.

III. WINDS AND CIRCULATION OF THE AIR.

- **1. Air in Motion.**
  Wind. Velocity of different winds. Order in the winds.
- **2. Causes of Winds.**
  Effect of heat. Of moisture.
- **3. General Circulation of the Atmosphere.**
  Location of constant ascending currents. Causes which complicate the circulation. Classification of winds.
- **4. Constant or Trade Winds.**
  General character. Direction. Cause of their westward trend.
- **5. Variable Winds.**
  Locality. Counter trades. Origin. Proofs. Direction. Polar winds.
- **6. The Calm Belts.**
  Equatorial. Calms of Cancer. Of Capricorn. Annual movement of calms and winds.
- **7. Periodical Winds.**
  Land and sea breezes. Benefits of. Monsoons. Cause. Effect. Bursting of monsoon. Minor monsoons. Other periodic winds. Mountain winds.
- **8. Offices of Winds.**

TEST QUESTIONS.—What is in general the "circuit" of the winds? Their general effect upon climate? What force is the primary cause of winds? What other force acts as auxiliary? Can you give any reason why the ocean of air is so much disturbed at the bottom, while the ocean of water is disturbed chiefly at or near the surface? Should the solar heat diminish, what would be the effect on the winds?

IV. STORMS.

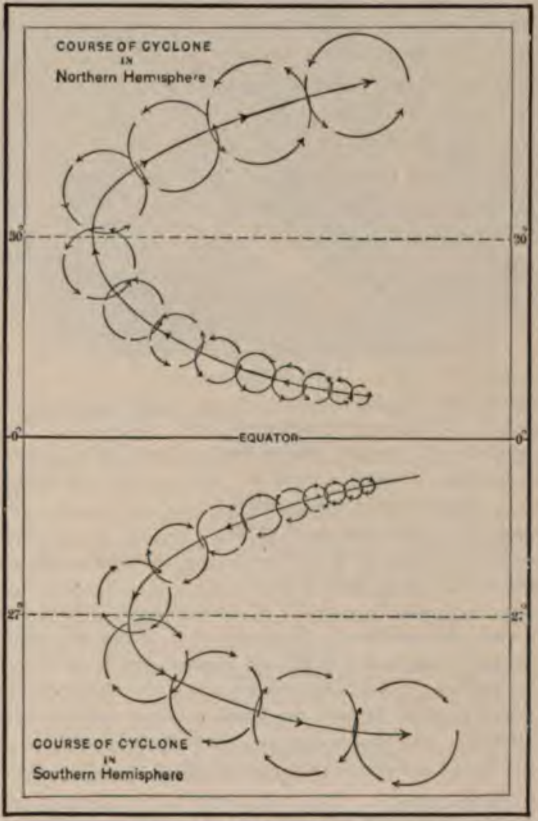
1. General Description.—Storms or tempests are sudden and violent commotions of the atmosphere. Especially at sea they are among the most grand and terribly sublime spectacles in nature. A wind becomes a storm when it attains the velocity of fifty miles or more an hour.

The great storms of the West Indies and of the Indian Ocean are called *hurricanes* and *tornadoes;* those of the China Sea, *typhoons.* [See Chart of the Winds.] These are alike in cause and character, and may best be considered under the general name of *cyclone.* This name, derived from the Greek *kuklos,* circle, refers to the fact that they consist of columns of air revolving round a perpendicular axis. At the same time they have a progressive motion of greater or less rapidity over a certain portion of the surface of the earth.

Illustration.—You have noticed, especially in autumn, little whirlwinds travelling along the roads or through the fields, and raising eddying or whirling columns of leaves and dust to a great height. These are miniature cyclones. They have both a revolving motion and a progressive one.

2. Cause of Storms.—The general cause of all such atmospheric disturbances is the same in principle as that of ordinary winds. It is a difference or inequality of pressure or weight, in different regions of the atmosphere. The principle may be thus stated: *into an area of low barometer a wind must always blow from an area of high barometer.*

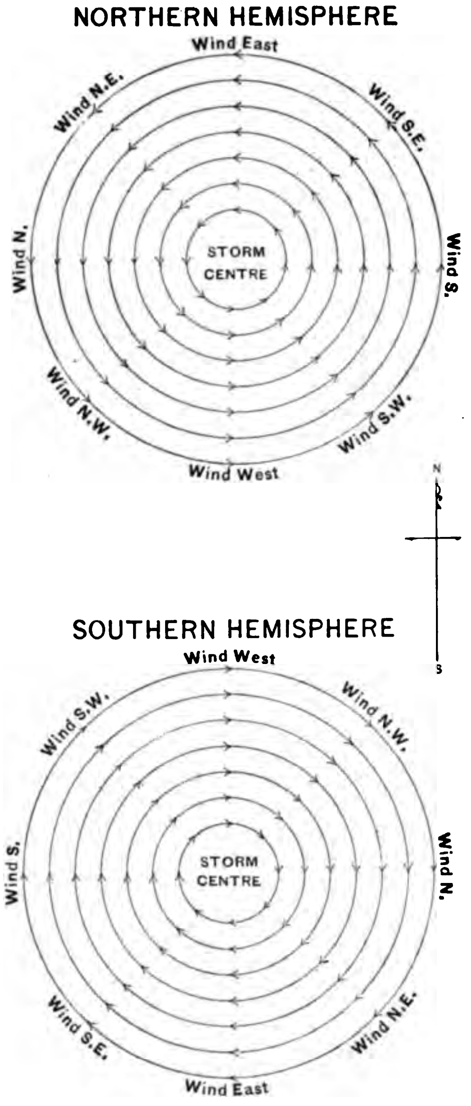
When from any cause the weight of the atmosphere in a locality is diminished, an ascending current results. Currents of colder and heavier air rush in to supply the deficiency. The force and velocity of the currents thus created will be greater or less according to the difference of atmospheric pressure, or the "gradient," as meteorologists call this difference. The larger the gradient, the more violent will be the resulting wind.



COURSES OF CYCLONES.

Now suppose there is one area of low barometer and one of high; the result will be a simple wind having one direction. But if the one area of low barometer have areas of high barometer on all sides of it, it is clear that from every one of these a current will flow in upon the area of low barometer. Such currents do not pass in straight lines to the centre of the area of low barometer, but circle round it in an ever-narrowing spiral, gradually ascending as they approach the centre. They constitute the cyclone.

Illustration.—The curves described by the air-currents of a cyclone may be readily illustrated. Fill a basin having a stopper in the bottom with water. Remove the stopper and observe how the water-currents take descending spiral courses. They move round the centre, but they also move toward the centre. They are like the air-currents of a cyclone turned upside down.



STORM CARDS.
(Showing direction of whirl in both hemispheres.)

3. Laws of Storms.—Cyclones obey the following well ascertained laws:

(1) *The wind revolves in opposite directions according as the cyclone is in the northern or southern hemisphere.* In the northern the direction of revolution is from right to left, or against the hands of a watch. In the southern it is from left to right, or with the hands of a watch. [See diagram, p. 81.]

The *whirl is caused* by the action of conflicting air-currents one upon another. These are all seeking the one area of low barometer. The strongest and most persistent will largely determine the direction of their united volume. In the tropics north of the equator the strongest and most persistent current is the northeast trade wind. It is met, however, we may suppose, by currents of equal or greater force from the west, the southwest, the south, etc. What will occur? It is easy to see how a northeast current may be driven out of its pathway and diverted toward the south, and how other currents coming in from the southeast may drive it to the northward; and thus a complete whirl be produced.

South of the equator the opposite effect may be similarly explained.

As the wind constantly revolves, it constantly changes its direction at any given place in the storm-track. On opposite sides of the centre it has opposite directions. Hence we see why the wind changes as soon as the storm-centre passes. This is shown by the "storm cards" on this page.

The rate of revolution, or "velocity of the wind," is from 50 to 150 miles an hour.

(2) *The storm, while revolving, has a progressive motion.* The *direction* of this motion is determined by the prevailing winds. In general it is northwest and southwest within the zones of the trades, and northeast and southeast in those of the counter-trades.

The course of cyclones is not necessarily horizontal or parallel to the surface of the earth. The revolving column frequently dips down at certain points in the line of its progress, and, again rising, leaves long distances untouched.

The course of tropical cyclones is well defined. North of the equator they move northwestwardly up to about latitude 30° N. Here they turn to the northeast. South of the equator they pursue the reverse course; starting near the tropics they advance toward the southwest, and near the parallel of 27° they turn to the southeast. From this it will be seen that the pathway of cyclones somewhat resembles the curve called a *parabola.* [See diagram, p. 81.]

The rate of travel varies from one to seventy miles an hour.

(3) *The storm-centre is an area of calm, and also of low barometer.* The arrival of the storm-centre at any point is indicated by the barometer. The descent of the mercury in tropical storms often amounts to two inches. It is sometimes so rapid that it can be detected by the eye.

This fall of the barometer occurs at the storm-centre for two reasons: 1st, because the centre is an area of warm, humid air (see p. 70); 2d, because the centre is an area of rarefaction.

To understand this, let us recur to our illustration above. It will be observed that in the case of the descending water-cyclone there is a central core which is entirely free from water. The particles near the very centre are driven away from it by centrifugal force. Just so the air particles which are nearest the vertical centre of the air cyclone are repelled outward from the centre by their centrifugal force. This makes the air in the centre less dense, or, as we commonly say, *rarefies* it. Sometimes it would seem that the rarefaction almost amounts to a vacuum.

STORM AT ST. THOMAS.—On the 29th of October, 1867, the island of St. Thomas was visited by a violent cyclone.

In the morning there was nothing unusual in the weather. The barometer stood at 30. At 11 o'clock, and without any warning from the barometer, a gale sprang up from the northwest. It blew for an hour. Then there was a great calm, which lasted 13 minutes. The barometer now fell more than two inches.

This showed that the centre of the storm had reached the island. So dense was the rain which now fell that objects 20 yards away were rendered invisible.

The 13 minutes of calm were the time during which the storm-centre was travelling over the island. When it had passed, there was a change in the wind. It had blown from the northwest; it now came from the southeast. [See storm card.] The storm at this time reached its height.

The masts of ships were literally whipped out of them. Every vessel in the harbor was wrecked, stranded, or dismasted. Large blocks of stone were lifted from the earth and blown about the streets. Houses were unroofed or carried along by the wind; and in the short space of four hours thousands of persons had been rendered houseless, 75 vessels had been wrecked or crippled, and 114 lost.

4. Anti-Cyclones.—Closely associated with cyclones are vast bodies of air the condition of which is the reverse of that of the cyclone. To such bodies of air is given the name *anti-cyclone* —*i.e.*, opposite of the cyclone.

The cyclone is warm, moist, and light. The anti-cyclone is cold, dry, and heavy. Hence the area over which an anti-cyclone prevails is one of high barometer. Occasionally in an anti-cyclone the mercury will rise to 31.25 inches.

Again (in accordance with the principle stated on page 81) while in a cyclone air-currents flow inward from the circumference toward the centre, in the anti-cyclone currents flow outward from the centre toward the circumference.

CAUSES OF ANTI-CYCLONES.—Heat causes the cyclone; cold, the anti-cyclone. At 15,000 feet above the sea level snow never melts. In other words, at the distance of about three miles from the surface of the earth there is a sphere of air at or below freezing temperature all round the globe. This is the reservoir of anti-cyclones. On page 77 is an account of their descent to the surface of the earth.

5. Value of Storm Laws.—A knowledge of the laws of storms is of the utmost value to the navigator. By observing the direction of the wind he may learn in what direction the storm-centre is from him. The rule is: *turn your back to the wind, and the low barometer is always to your left in the northern hemisphere, and in the southern hemisphere to your right.* This will appear by examining the diagram on page 81, and imagining yourself with your back to the arrow heads. If the sailor knows whereabouts the storm centre is, he knows how to steer away from it.

Again: suppose he finds his barometer sinking rapidly, an inch or more below its usual height. He now knows that he is in the storm-centre. Obviously it will be well to trim the sails and prepare for a gale. The centre of calm will soon pass beyond him and a tempest will strike him.

6. The Areas of Storms differ in size and shape. In Europe they are nearly circular; in the United States, their shape is usually an elongated oval. As to size, they are seldom less than 600 miles in diameter. They average twice that amount.

7. Tornadoes and Whirlwinds differ from hurricanes and typhoons, (1) in duration; and (2) in extent of area.

WATER-SPOUT AT SEA.

In passing over any point, tornadoes seldom occupy more than a few seconds. Their breadth varies from a few yards to a mile or two, though their destructive effects are usually confined to a narrow path.

The rate of their progressive motion is commonly about 30 miles an hour, and the length of their course 25 or 30.

A tornado approaching is seen as a huge funnel-shaped cloud pointing downward. A noise, perhaps due to electricity, and not unlike that of a train of cars, is heard; thunder, lightning, hail, and rain occur.

A partial vacuum is formed by the centrifugal force at the centre. Sometimes when the end of the funnel dips down and touches a building, the vacuum resting over it so relieves the building from atmospheric pressure as to cause a sudden expansion of the air contained in it. Its walls then burst asunder as by explosive force. Tornadoes sweep everything before them. Houses are lifted up bodily, and lanes called "wind roads" are cut through the forests. Large trees are up-rooted and whirled about like stubble.

The region most frequently visited by tornadoes is the Mississippi Valley. During the past 50 years more than 600 have occurred there.

Dust Whirlwinds.—In the deserts of Asia and Africa, whirlwinds sometimes draw up into their central core vast quantities of sand and dust. They thus become moving columns of sand, 500 to 700 feet in height (as observed with sextant), and are known as "dust whirlwinds."

The *Samoom* or "poison wind" appears to be a desert whirlwind intensely hot, and so rarefied as to be suffocating.

Waterspouts.—At sea whirlwinds sometimes produce waterspouts. They correspond to the dust whirlwinds of the desert. The air-current, revolving like that of a cyclone, takes up the spray of the waves into its core of low pressure [see p. 82, (3)], and the tall column moves over the waters with extraordinary speed.

8. Distribution of Storms.—[See Chart of the Winds.] The most violent storms occur in the vicinity of mountainous islands.

The Pacific is the most tranquil of the oceans. In those portions of its trade-wind regions where there are no islands, and where monsoons do not prevail, storms are unknown. The typhoons are confined to the southeast coasts of Asia and the East India Archipelago.

The South Atlantic, along the coast of intertropical Brazil, is almost stormless, whereas, in corresponding latitudes in the North Atlantic, among the West Indies, terrific hurricanes occur.

The portions of the Indian Ocean specially subject to hurricanes are the Bay of Bengal and the neighborhood of Mauritius.

9. Weather Forecasts.*—During the last forty years observations upon the force and direction of the wind, the course and character of storms, the pressure of the atmosphere, the amount of rainfall, the temperature and moisture of the air, have disclosed certain general principles or laws of the weather.

Knowing these laws, and knowing by telegraphic reports the weather-conditions prevailing throughout the country, we are enabled to predict from day to day, with considerable accuracy, the approach of storms, or of cold or hot weather.

Great Storms of the United States.—Most of our great storms consist of northeasterly winds, and travel in a northeasterly direction. They may be conveniently classed as those which come to us from the Pacific Ocean, and those which come from the Atlantic.

The storms of the Pacific penetrate to a greater or less distance into the country, and often cross it entirely. Their general direction is eastward.

The storms that come from the Atlantic are first felt either at some southerly point on the Atlantic seaboard, or on the shores of the Gulf. Generally they come in from sea by the way of the Gulf, pass northward through the Mississippi Valley, and then turn to the northeast.

Those which make their appearance first on the Atlantic seaboard are the western halves of cyclones, which, pursuing their parabolic course, first northwestwardly and then northeastwardly, happen partially to embrace our shores within their area. These western half-cyclones consist of northeast and northwest gales. The eastern halves of the same storms, consisting of gales from the southwest and southeast, are at sea. The storm-centre pursues a course nearly coinciding with our shore line.

Prediction of Storms.—The transient and uncertain character of *tornadoes* renders it impossible to make exact predictions regarding them.

Ordinary storms, however, are so far regular that, in a large proportion of cases, their course,

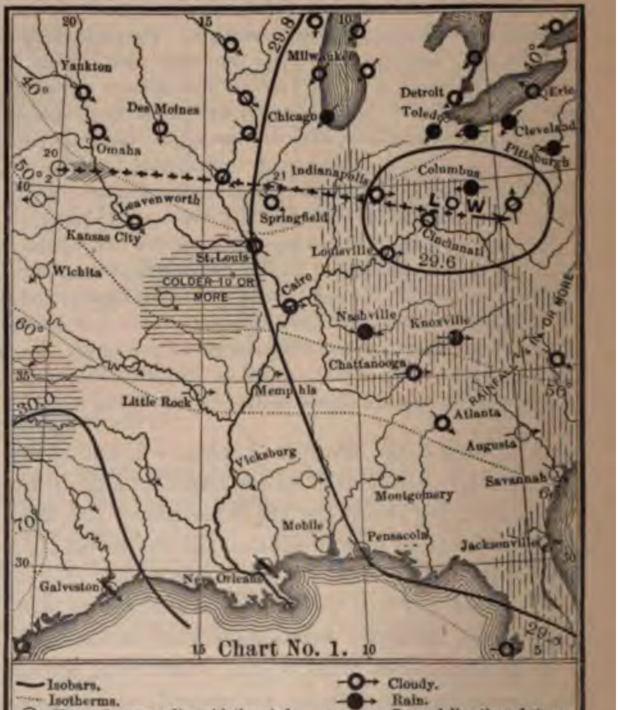


Chart No. 1.

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* Forty years ago the author of this work urged upon the attention of the government of the United States, and those of European nations, the desirability of having systematic meteorological observations carried on by all nations at sea. As the result of his efforts the United States government invited all the maritime States of Christendom to a conference, which took place in Brussels, 1853. The suggestions made were adopted. But the ideas of Lt. Maury were not limited to the ocean. In the preface to the second edition of his "Physical Geography of the Sea," published in 1855, he says: "It is a pity that the system of observations recommended by the conference should relate only to the sea. The plan should include the land also, and be universal." The present "U. S. Weather Bureau" with its well-organized Signal Service, is the crowning result of his labors in this direction. —*The Reviser.*

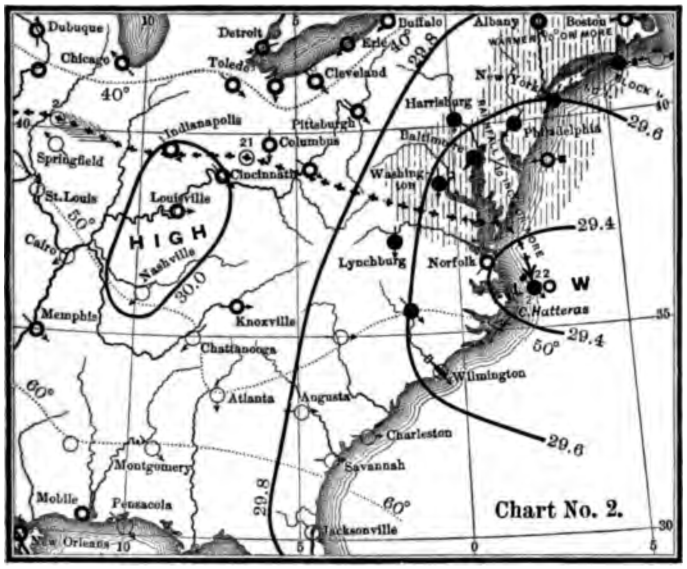


Chart No. 2.

after they have once manifested themselves, may be foretold with some degree of accuracy.

Simultaneous observations are made at 160 stations scattered over the country, at 8 A.M. and 8 P.M. every day. These observations are telegraphed to the central office of the Weather Bureau, at Washington. There they are examined, and it is ascertained what they indicate.

A storm begins, as we know, within or near an area of low barometer.

Look at Chart No. I. On March 21, 1891, at 8 P.M., a storm-centre, marked "Low," was near Cincinnati. What weather shall we predict for the next day on the Atlantic coast?

(1) As the cyclone is in the region of prevailing westerly winds, it must be drifted to the eastward. We may safely predict that its centre will reach the Atlantic.

(2) Since it will enter a more moist atmosphere when it nears the ocean, we may also predict rain on the seaboard.

(3) As its rotation is counter to that of the watch hand, we may be sure that the winds will be easterly and northeasterly in the N. W. quadrant or quarter of its area, and northerly to westerly in its S. W. quadrant. [See Storm Card, p. 82.]

(4) As the storm advances, it draws warm air from the south and the Gulf Stream into its front and cool air from the Lakes into its western side. Consequently, we may predict a rise of temperature on the Atlantic coast and a fall of temperature west of the Alleghanies.

In fact, on the night of March 21, 1891, with Chart I before him, a weather forecaster did make just such predictions for the next day, viz.: "The western storm will continue its easterly movement. In the Middle States, cloudy and partly cloudy weather, generally warmer, will prevail, with rain and northeasterly winds; in New England, northeast winds with rain or snow at night."

Chart II.—These forecasts were substantially fulfilled. Chart II shows the actual winds, etc., at 8 P.M., March 22. The day began with high northeast winds, and rain on the coast at Cape Hatteras, winds causing great damage on the Jersey coast, and attaining a velocity of forty miles an hour at Block Island by night.

This explains how the weather is foretold. The Weather Bureau telegraphs its "weather probabilities" daily all over the country, and by its bulletins forewarns us of approaching wind and rain, heat and cold. On the approach of a storm, cautionary signals are displayed at the lake ports and at those of the Atlantic coast. The annual saving of life and property due to these warnings is immense.

TOPICAL ANALYSIS.

IV. STORMS.

1. **General Description.**
   Hurricanes and tornadoes. Typhoons. Cyclones.
2. **Cause of Storms.**
   Cause of spiral movement. Illustration.
3. **Laws of Storms.**
   Direction of the whirl. Forward motion of the storm. Calm at the centre. Causes of low barometer at centre. Storm at St. Thomas.
4. **Anti-Cyclones.**
5. **Value of Storm Laws.**
6. **Area of Storms.**
7. **Tornadoes and Whirlwinds.**
   Difference between these and hurricanes. Destructive effects. Dust whirlwinds. Waterspouts.
8. **Distribution of Storms.**
9. **Weather Forecasts.**
   Great storms of the United States. Prediction of.

TEST QUESTIONS.—Is there any relation between the frequency and power of storms and the temperature of the places where they occur? Why do they form more sublime spectacles at sea than on land? When the earth was much hotter than now, what must have been the character of the storms? Why?

V. MOISTURE OF THE AIR.

1. Amount.—More or less moisture is always present in the air. It exists as vapor. This vapor is invisible, yet we can estimate its amount. The rivers measure it for us. What they discharge into the sea has been taken up as vapor from the sea. The general law regarding the amount of moisture in the atmosphere is, that *the warmer the air, the more moisture it can contain.*

2. *Evaporation.*—One of the most wonderful of the many wonderful properties of water is the readiness with which it passes from one of its forms to another. The assuming of the condition of vapor is termed *evaporation.*

Evaporation goes on at all temperatures and in all circumstances until the air is saturated.

Illustrations.—You may have observed water drying in our streets and roads after a rain, or clothes hanging on the line frozen stiff, and yet becoming dry; or you may have seen a light fall of snow disappear in freezing weather. These were all cases of evaporation.

Evaporation is accelerated and augmented (1) by high temperature; (2) by diminution of pressure; (3) by a dry condition of the atmosphere; (4) by wind.

EFFECT OF TEMPERATURE. — *The higher the temperature, the greater and more rapid will evaporation be.* Hence we find the maximum of evaporation within the tropics; the minimum at the poles. Evaporation takes place chiefly through the day, and in the warmest part of the day.

EFFECT OF PRESSURE.—*The less the atmospheric pressure, the more rapid will evaporation be.* In a vacuum there is almost no pressure, and there evaporation takes place almost instantaneously. Hence on the tops of high mountains, where the pressure of the atmosphere is very much diminished, evaporation goes on much more rapidly than it does at the sea-level, where the full pressure of the entire atmosphere is felt.

Indeed mountain peaks may be so high as to be entirely free from snow, while a belt of snow girdles the lower part of the mountain. The reason of this appears to be that at certain altitudes snow evaporates so rapidly that it cannot accumulate.

Aconcagua in Chili sometimes appears with its bare and bleak top peering above a girdle of snow.

EFFECT OF DRYNESS.—Atmospheric air can absorb or take up a certain amount of moisture. Warm and dry air will absorb far more than cool and damp. When air has absorbed all the moisture that it can retain, it is said to be *saturated.* Now if the air be near the point of saturation, it is clear that evaporation will be retarded, while again if the air be dry, it will be encouraged.

In a damp, foggy atmosphere you see every breath that you discharge. The air has all the moisture that it can contain, and has no absorptive capacity. In a dry warm air your breath is invisible. It is absorbed as soon as it leaves your mouth.

EFFECT OF WIND.—If a wind blow upon the surface of water, evaporation is accelerated. This is because as fast as one portion of the air becomes charged with vapor, it is removed, and a fresh portion takes its place.

3. *Condensation and Precipitation.*—Vapor returns to the liquid or solid state and is deposited upon the earth by the processes called condensation and precipitation.

When condensed, it assumes the form of dew, white or hoar-frost, fog or cloud, hail or snow.

The great cause of precipitation, or the removal of moisture from the atmosphere, is loss of heat. The atmosphere can contain more or less vapor in a state of absorption in proportion to its temperature. If the temperature be 50° Fahr. a cubic foot of air can absorb about 2 grains' weight of vapor. At the temperature of 70° Fahr., *i.e.*, with an increase of only 20° of heat, the proportion of vapor is about twice as great.

From this it is easy to see why reduction of temperature causes precipitation. Suppose a cubic foot of air saturated with moisture to be reduced in temperature, even very slightly; it is obvious that its capacity for moisture will be at once reduced, and a certain portion of its vapor must be precipitated. The temperature at which the deposit in such cases begins to take place, is called the *dew-point.*

4. *How Dew is Formed.*—On clear and calm nights, the grass, the leaves, and other objects rapidly radiate their heat and grow cool. They chill the surrounding air. It can no longer contain the same amount of moisture as when it was warm. Hence a portion of it is condensed and deposited upon the leaves in the shape of fine drops of water. We often say "the *dew begins to fall,*" though, strictly speaking, it does not fall. It is deposited upon the grass precisely as, on a hot summer's day, the moisture is deposited on the outside of a pitcher of ice water.

Clouds check radiation, and hence on cloudy nights less dew, or perhaps none at all, is deposited.

You must have noticed that dew, and hoar-frost, which is the same as dew, only frozen, are deposited on some objects more copiously than others. This is because some radiate heat more rapidly, and therefore chill and condense more quickly the vapor that floats above them.

5. *Fog.*—Vapor coming in contact with cool air, if chilled below the dew-point, becomes visible. It assumes the form of fine watery particles which we call *mist* or *fog.*

Illustrations.—The condensation of your breath into mist, as it passes from your mouth into the cold air, is a familiar illustration of this.

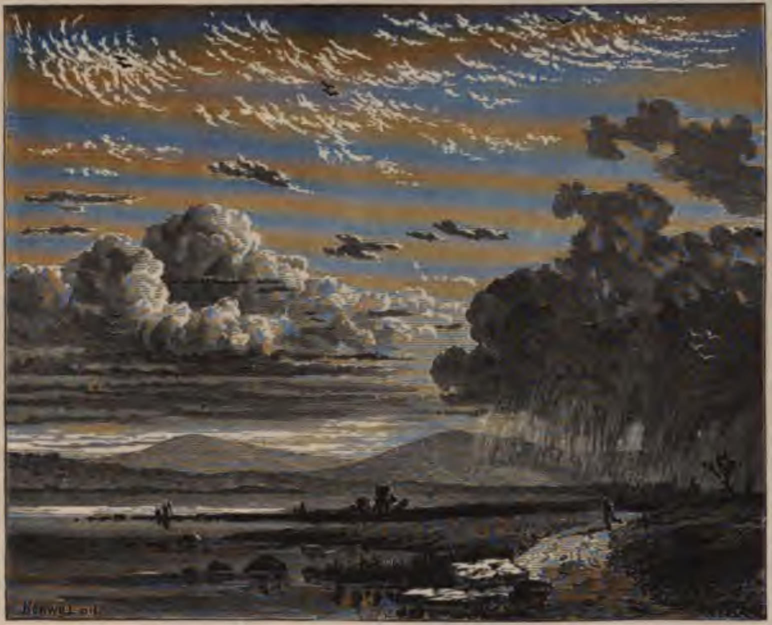
You may also have observed that in a clear, calm, and frosty morning the springs, ponds, and rivers "smoke." This is the same phenomenon that is exhibited by the steam which issues from the tea-kettle, the locomotive, and the steamboat. The "smoke" is a miniature fog.

Very often, too, fogs are seen upon the surface of rivers in the early morning. Toward noon they vanish. The morning air, because cool, cannot retain so much moisture in absorption, but when the rays of the sun have warmed it, and increased its capacity for moisture, it absorbs the vapor, and the fog disappears.

The most foggy sea in the world is that part of the North Atlantic Ocean that lies on the polar side of latitude 40°; and the most foggy place is on the Grand Banks of Newfoundland.

Vapor rises rapidly from the warm water of the Gulf Stream. Near the Grand Banks the Gulf Stream meets the icy Labrador current. Owing to the chilling influence of this current the vapor is condensed into fog as fast as it rises.

Though fogs are most frequent in summer, they occur on the Grand Banks at all seasons, producing in winter the exquisitely beautiful silver fogs of Newfoundland, which garnish the forests of that island with frostwork.



FORMS OF CLOUDS.

1. Cirrus.
2. Cumulus.
3. Stratus.
4. Nimbus.

6. Clouds.—A cloud is simply a mass of mist or fog floating high in the air instead of near the ground.

Clouds present a very great variety of appearance, and hence are divided into seven classes: three simple, *cirrus*, *cumulus*, and *stratus*; four compound, *cirro-cumulus*, *cirro-stratus*, *cumulo-stratus*, and *cumulo-cirro-stratus* or *nimbus*.

CIRRUS.—The cirrus or curl cloud consists of white wavy lines or curled bands. It is the lightest of all cloud-forms, and attains the highest elevations, floating four or five miles above the surface of the earth in regions of perpetual frost. It is supposed to consist of minute crystals of ice such as we see in the snowflake, and may be defined as frozen fog.

Cirrus clouds are often heralds of the cyclone. These nimble forerunners have been observed 800 miles in advance of a storm. They sometimes caution the mariner, ere his barometer gives any intimation of the approaching tempest.

CUMULUS clouds derive their name from the fact that they are heaped up, like vast mountains towering one upon another. They are often of glistening whiteness. They abound in the tropics, and frequently appear in the sky of temperate latitudes during the summer, when evaporation is rapid. Of all cloud-forms they are perhaps the grandest. Out of them darts the lightning which makes our thunderstorms so magnificent.

STRATUS clouds appear in the shape of long layers or ribbons. They are seen most frequently in the evening, and, when tinged by the rays of the setting sun, they form those islets of gold which render the sunset sky so beautiful.

The compound clouds combine the features of the simple ones from which they are named.

THE CIRRO-CUMULUS is made up of fleecy masses of cirrus which roll themselves up into rounded shapes. These cause the mottled appearance commonly known as a "mackerel sky."

THE CIRRO-STRATUS consists of layers of cirrus clouds. They are often so arranged as to resemble a shoal of fishes, all swimming parallel to one another. This cloud, like the cirrus, is often the precursor of storms.

THE CUMULO-STRATUS is formed of heaped clouds resting on layer clouds. Like the cumulus, its general mass is often quite dark and threatening, while its edges are bright with sunshine that is behind the clouds.

THE CUMULO-CIRRO-STRATUS, or *nimbus*, is simply a cloud of any kind from which rain falls. Heaped clouds, and curls and layers blend together, lose their characteristic features, and form one dense leaden mass. It often overspreads the whole heavens.

VELOCITY.—The velocity of cloud movement, when accurately estimated by observers, is found to be far more rapid than we should suppose from the apparent rate of the "passing cloud." It has been found that cirro-cumulus and cirrus clouds which seem to be moving at a leisurely rate are often travelling 75 to 100 miles an hour.

This is of very great interest, for it indicates to us the velocity of the upper currents of the atmosphere.

HEIGHT OF CLOUDS.—When clouds rest on the tops of mountains, they are actually in contact with the earth; often indeed they are below the summit of the mountain. Their average elevation, however, is about half a mile. At times they cannot be less than four or five miles high.

WHY THE CLOUDS DO NOT FALL.—Clouds are not vapor; they consist either of minute vesicles—that is, tiny hollow globes of water—or of fine ice-crystals. In either case they are much heavier than air. Why, then, do they not fall? So far as we know, they are falling constantly. But the lower part of the cloud, as it comes into warmer air, is dissolved again to vapor, and disappears, while a new portion may at the same time be formed above. Thus the cloud, though constantly sinking, retains its place.

A different view is proposed in a recent theory. It is that clouds consist of minute watery particles which have attached themselves to motes floating in the atmosphere, and that these buoy them up.

OFFICES OF CLOUDS.—Aside from their duty as water-carriers the main offices of clouds are two: (1) they screen the earth from excessive heat in summer, while in winter they are a mantle to keep it warm by checking radiation.

Plants and animals are distressed by the intense heat of the noonday sun. But the more powerful the ray, the more rapid is evaporation. Soon vapor enough is lifted from the earth to form the mitigating clouds. They overshadow the land, and plants and animals rejoice in their shelter.

(2) They enhance the beauty of the natural world. A pure blue sky, unvaried day after day by a cloud, is not to be compared with one in which azure and white are contrasted. Nothing is more missed by the traveller in Egypt than the grandeur of our storm clouds and the varied beauty of our evening skies.

7. Rain.—The first form assumed by the moisture of the upper air when condensed is that of cloud.* If, however, the process of condensation continue, and vapor exist in abundance, it is easy to see that the tiny water particles which make up the cloud will increase in size, until they are too heavy to float, and will fall as raindrops to the earth.

The general cause of rainfall is that a certain volume of vapor-laden air has been chilled below the dew-point, so that it has no longer the same capacity for moisture as before. This may be brought about in several ways: (1) the moist air may be driven up a lofty mountain slope into the higher and colder regions of the atmosphere; (2) it may be carried upward as an ascending current of heated air; (3) it may be chilled by being mixed with a mass of colder air; (4) it may be chilled by being expanded, when drawn into the centre of a cyclone. Such a centre (p. 82) is an area of rarefaction. Hence air entering it will expand, and expansion has the effect of cooling it and condensing its vapor. This last cause produces the heaviest rainfalls for short periods.

8. Distribution of Rain.—Rain is very unequally distributed over the earth.

(1) The rainfall is greater on land than at sea.

(2) It is greater in mountainous than in level regions.

The reason of both these facts is, that elevations have the effect of directing vapor-laden air into the higher, cooler regions of the atmosphere.

(3) The rainfall is greater in the torrid than in any other zone. The average annual quantity at the equator is eight feet. It diminishes as we approach the poles. This follows from the fact that the torrid zone, being the hottest, is that of the greatest evaporation.

These are the general facts regarding the distribution of rain. We must now consider how this distribution is brought about.

9. Regulators of Rainfall.—The great regulators of the rainfall are the mountain chains, the deserts, and the winds. Each of these has an important part to perform in distributing the rain over the surface of the earth.

INFLUENCE OF MOUNTAINS.—*The mountains are the great condensers of vapor.* If mountain chains face the winds that come from the sea, they render the region between themselves and the sea a well-watered one. They not unfrequently make rainless the region beyond them. They rob the winds of their moisture.

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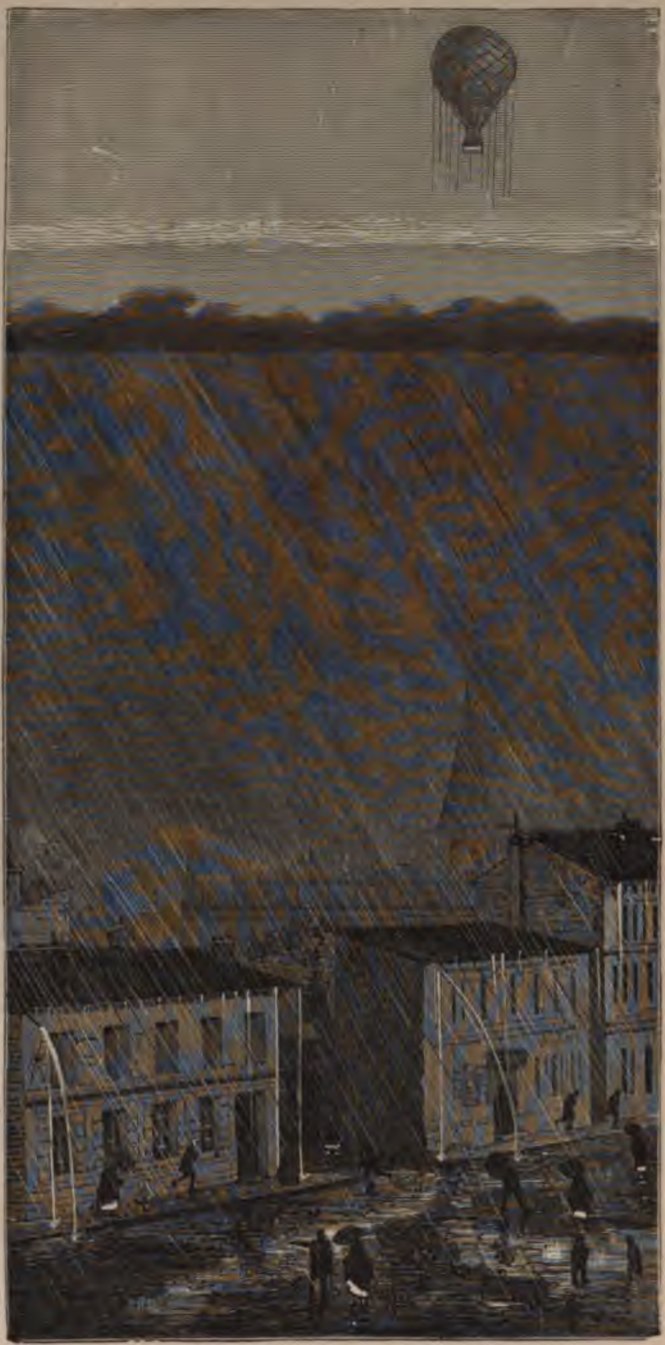
* Rain sometimes falls from a cloudless sky. In such cases vapor is condensed directly into water, without passing through the intervening stage of cloud.



VIEW OF THE ATMOSPHERE DURING A RAIN-STORM.

In India.—Thus the Himalayas face the southwest monsoon, as it comes freighted with vapor from the Indian Ocean. They make India one of the most productive countries in the world; but the plateaus lying to the north of them are almost rainless. On a smaller scale the Western Ghauts act in the same way. They, too, lie in the pathway of the monsoons, and intercept and condense their vapors. The annual rainfall upon their tops amounts to about 260 inches, while the country on the east of them receives less than 30 inches.

But perhaps the most striking illustration of the influence of mountains upon rainfall is to be found in the case of the Khasia hills, on the northern shores of the Bay of Bengal. They intercept the southwest monsoons, as they come burdened with vapor from the bay. The result is that the winds, as they slant up the hills into the higher and cooler air, have their moisture at once precipitated as rain, of which about 500 inches fall there in the year.

In South America the influence of the Andes is familiar. The northeast and southeast trades come from the sea saturated with vapor, and so go into the interior, rising, and cooling, and dispensing showers as they go, until they reach the crest of the Andes. Here the cold is sufficient to squeeze almost all the remaining moisture from them. Thus the eastern side of these mountains, within the trade-wind region [see Chart of the Winds], is abundantly watered, while the western is dry. Hence it is that Peru is a rainless country.

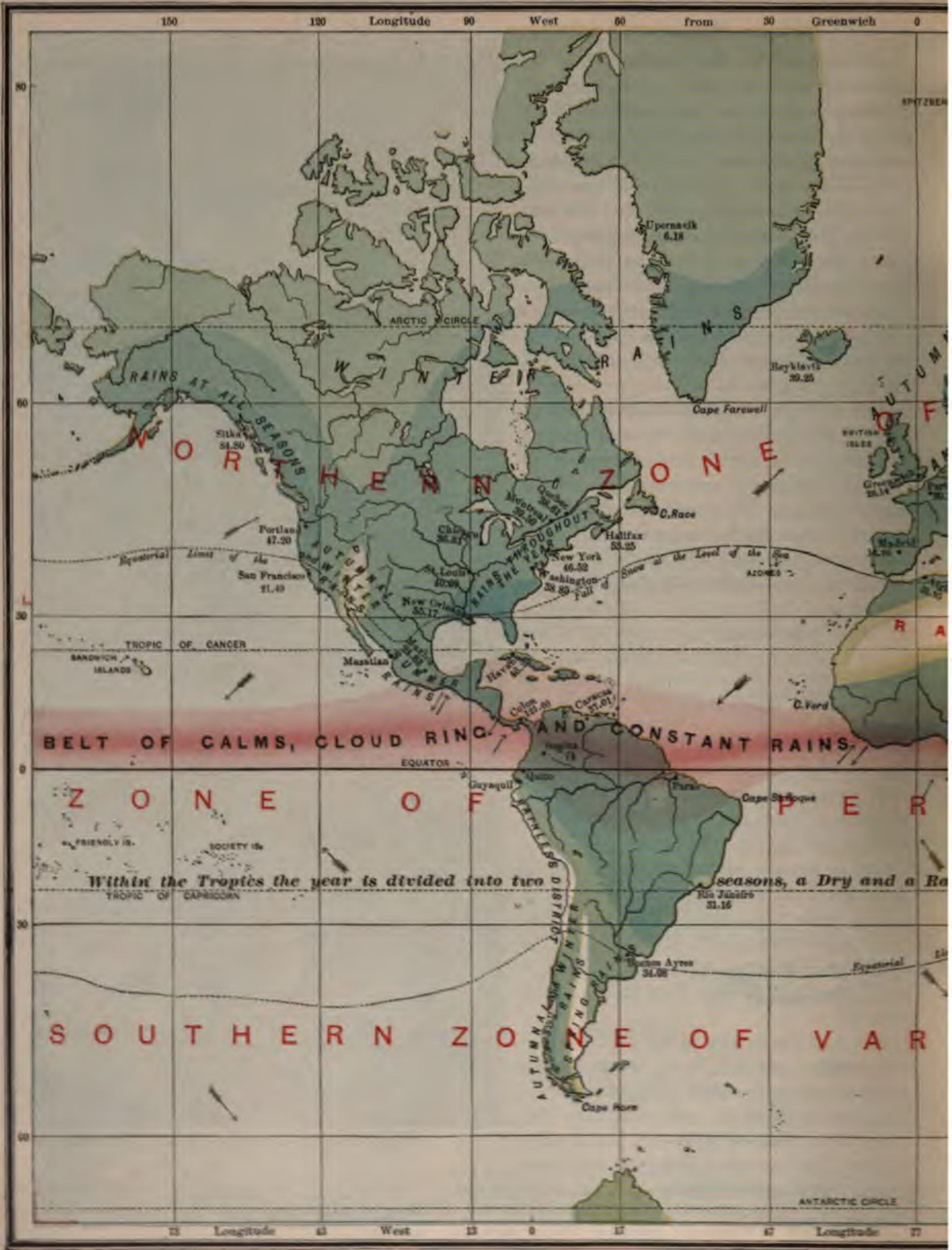
South of the mouth of the La Plata, the reverse takes place. There the prevailing winds are from the west. They come from the Pacific, reeking with moisture, and water the western slopes of the Andes, causing the excessive rains of Southern Chili. The eastern slopes are comparatively dry.

In our own country the Cascade Range and the Sierra Nevada have a similar influence. They lie in the pathway of the westerly winds which come loaded with moisture from the Pacific. They act as condensers, and bring down the copious showers which give fertility to the Pacific slope.

INFLUENCE OF DESERTS.—In many cases the deserts are the directors of the winds, and thus become regulators of the rainfall.

India is in a region in which the northeast trade winds blow over the land, and are rainless. Were it not for the deserts of Central Asia, which have the effect of drawing in the southwest monsoons [see p. 80], India would be as arid as Gobi.

In Africa the Sahara produces the monsoons which blow from the Indian Ocean upon that continent. By the month of June, the desert is heated up sufficiently to bring in the sea winds. The rainy season then begins, and lasts till late in autumn.



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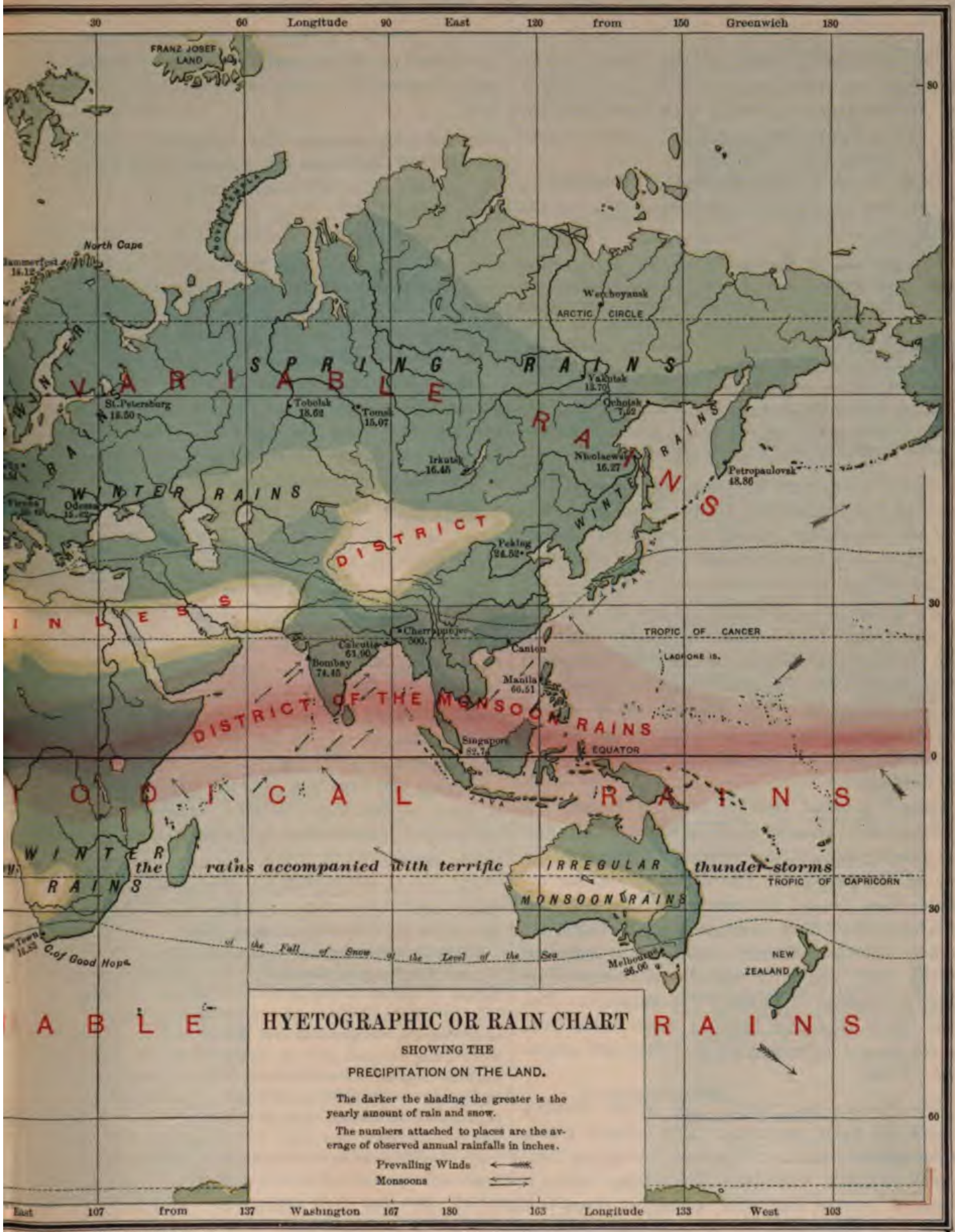
QUESTIONS ON THE RAIN CHART.

How is the larger or smaller amount of annual rainfall indicated on the chart? How are monsoons indicated? Where is the district of the great monsoons? What portion of the earth's surface has the greatest annual rainfall? What winds bring the rains to this region?

Trace the northern and southern limits within which snow does not fall at the level of the sea. Where do the periodical rains prevail? How is the year divided within the limits of the periodical rains?

Where is the belt of constant rains? By what phenomenon are these rains usually accompanied? Name some countries in which these rains prevail.

What parts of North America have the greatest



HYETOGRAPHIC OR RAIN CHART

SHOWING THE

PRECIPITATION ON THE LAND.

The darker the shading the greater is the yearly amount of rain and snow.

The numbers attached to places are the average of observed annual rainfalls in inches.

Prevailing Winds	←
Monsoons	⇄

BY THE UNIVERSITY PUBLISHING CO., N. Y.

annual rainfall? What countries of South America? What countries on the east and west shores of Africa? What portions of Asia? Of Australia? Give the reason in each case.

At what season are the rains of Europe most frequent?

In what parts of North America does rain occur throughout the year?

Where do autumnal and winter rains prevail? What is the agricultural effect of the distribution of the rainfall?

What places in the United States have the heaviest rainfall? Give the reason in each case.

What rainless regions are indicated on the chart? Why are these districts rainless?

The periodical overflow of the Nile is due to the rains into which the vapor is condensed which the African monsoons bring with them from the sea. Thus Egypt owes its fertility in some degree to the burning sands of Sahara.

North America has its deserts and its monsoons, though they are far less marked than those of the Old World.

The table-lands of Mexico, Arizona, the dry plains of Texas, New Mexico, and the neighboring regions, are heated by the summer sun to such a degree, that the air resting upon them becomes rarefied, and ascends, the cooler air from far and near coming in to restore the equilibrium. Thus a southeast monsoon is created in the Gulf of Mexico, and a southwest one in the Pacific.

Both of these winds blow toward the land, and bring the rains to Mexico, so that one side of that country is watered from the Pacific, the other from the Atlantic Ocean.

INFLUENCE OF THE WINDS.—As a general rule winds are dry, if they have traversed the land, or if they are journeying toward the equator. Winds are wet, if they have traversed the sea, or if they are journeying from the equator.

Dry Winds.—Land winds are dry for the simple reason that they have so little opportunity to take up moisture. Thus the northeast monsoons which sweep over the inland regions of Asia are the dry monsoons. The westerly winds of our own country, all the way from the Sierra Nevada to the Atlantic, are dry winds. They bring our fair weather.

Again: a wind that is blowing toward the equator is dry, because, entering warmer latitudes, it is gaining capacity for moisture with every degree of its progress. The trade winds, for example, blow toward the equator. You perceive, therefore, that they are going from cooler to warmer latitudes. Their temperature is increased by the way, and with increase of temperature there is increase of capacity for moisture. The trade winds, therefore, take up more water from the sea than they return to it. They are evaporating winds.

Wet Winds.—Sea winds and winds blowing toward the poles are rainy. The counter trades go toward the poles. They are travelling from warmer to cooler latitudes. Their temperature is decreased by the way, and, therefore, there is a decrease in their capacity for moisture; they deposit more than they take up. They are, therefore, rain winds.

10. Rains Classified.—The winds are classified according to the regularity with which they blow, as constant, variable, and periodical. It is proper, therefore, to classify the rains which they bring in the same way. Hence, *according to the nature of the supplying winds, the rainfall in any given region is* Constant, Periodical, *or* Variable.

CONSTANT RAINS.—The constant rains are confined to a belt near the equator, about 5° wide. In this belt there are almost daily showers. The cause is clear.

The northeast and southeast trades meet near the equator. They are so completely saturated with moisture that the sailor, hanging out his clothes in the morning, is often surprised to find in the evening that they have not dried in the least. Under the vertical rays of the sun an ascending current is produced which carries the vapor-laden air into the higher regions of the atmosphere. Here the vapor is cooled and condensed; and hence the frequent thunder showers of this region of constant precipitation.

PERIODICAL RAINS.—Within the tropics, to the north and to the south of the narrow belt of Constant Rains, lie the zones of Periodical Rains.

In the New World the periodical rainfall is closely connected with the annual movement of the Equatorial Calm Belt and its accompanying Cloud Ring.

The Calm Belt travels northward and southward, following the annual movement of the sun in the heavens. It is farthest south in March, and farthest north in September.

During the time that it is passing over a place, it gives to that place its rainy season. After it has passed, there is scarcely a drop of rain until it comes again.

Let us follow the cloud ring in its journey from south to north, and you will readily understand its movements, and the rainy seasons that depend upon them.

The time is February; it is then over Guayaquil (lat. 3° S.), and then the rainy season there is at its height. It commences its movement for the north in March. Quitting the skies of Guayaquil soon after, it leaves them bright and clear with the commencement of the dry season. In a little while it has travelled as far as latitude 4° N. It then overshadows Bogotá, where the rains begin in April or May. In June it is over Panama, and hence a rainy season prevails there; and so the cloud ring continues on to Mexico, reaching Mazatlan, just under the tropic, about September, when it commences its march toward the south, so as to be again at Guayaquil by February or March.

It is clear that on its return from north to south the cloud ring must give to certain places a second rainy season, because, in coming and going, it passes over them twice.

In the Old World the periodical rains are occasioned by the monsoons or reversed trades. For about six months, in Southern Asia and Central Africa, copious rains fall. When the monsoons change, the dry season sets in, and scarcely any rain falls until after six months, when the wet monsoon begins to blow again.

Rainy and Dry Seasons.—Within the belt of the Periodical Rains the year is divided into rainy seasons and dry.

In general terms, the rainy season in the northern belt may be said to begin with April, and last till October, while the dry season extends from October till April. In the southern belt this order is reversed—the dry season lasting from April till October, and the season of rain from October till April.

It is not to be supposed that during the rainy season there is an incessant fall of rain. In Mexico, for instance, the rainy season is the most delightful portion of the year. As a rule, the nights and mornings are clear and beautiful, and the weather fine, with a few hours of rain after three or four o'clock P.M.

VARIABLE RAINS.—North and south of the belts of Periodical Rains, the rains become Variable; *i.e.*, they are irregularly distributed through the year. In some countries they occur mainly during the summer, in others during the winter; in others, again, during the spring and autumn. This condition of things prevails throughout the temperate regions.

11. Excessive and Deficient Rainfall.—Owing to the influence of local causes, there are regions of excessive and deficient rainfall. Let the pupil, now familiar with the influence of the winds, the mountains, and the deserts, refer either the excess or the deficiency in the cases about to be mentioned to its appropriate cause. [See Rain Chart.]

REGIONS OF EXCESS.—Naturally the regions of excessive rainfall, with few exceptions, lie within or near the tropics. Cherrapunjee, in the vicinity of the Khasia hills in India, receives annually about 500, and in some years 600, inches—or a depth of fifty feet—a greater amount, so far as we know, than any other place on the globe.

Parts of the British Isles, the coasts of Guinea and Senegambia, Eastern Africa and India, are all remarkable for their heavy rainfall.

In the New World, Brazil, Guiana, Venezuela, the West India Islands, Central America, Patagonia and the Pacific shores of Alaska are all regions of excessive rainfall.

REGIONS OF DEFICIENCY.—Rainless or almost rainless regions are the great belt of deserts extending across Africa and Asia, from the Atlantic nearly to the Pacific; the Great Basin in North America, lying eastward of the Sierra Nevada; Peru, together with the northern part of Chili, and portions of the Argentine Republic lying eastward of the Andes.

Cultivation in all dry countries is carried on by means of irrigation. For this purpose tanks have been constructed in India at vast expense. The Peruvian farmers avail themselves of the mountain-streams that are fed by the snows of the Andes: while the peasant of Egypt, like his forefathers, supplies his fields and gardens from the sacred waters of the Nile. (For irrigation in U. S. see Recent Facts.)

TOPICAL ANALYSIS.

V. MOISTURE OF THE AIR.

1. Amount.

How measured.

2. Evaporation.

Conditions under which it takes place. Causes which increase it. Effect of temperature. Consequent place and time of maximum evaporation. Effect of pressure. Effect of dryness. Effect of winds.

3. Condensation and Precipitation.

Cause of precipitation. Dew-point. Forms of water derived from vapor.

4. How Dew is Formed.

Effect of clouds. Difference in quantity of dew or frost formed on various substances.

5. Fog.

How formed. Illustrations. Fogs of the Grand Banks.

6. Clouds.

Various forms. Cirrus. Cumulus. Stratus. Cirro-cumulus. Cirro-stratus. Cumulo-stratus. Cumulo-cirro-stratus. Velocity of cloud movement. Height of clouds. Why the clouds do not fall. Offices of clouds.

7. Rain.

General cause. How brought about.

8. Distribution of Rain.

How caused.

9. Regulators of Rainfall.

Influence of mountains. The Himalayas. Western Ghauts. Khasia hills. The Andes. The Cascade Range and Sierra Nevada. Influence of deserts. Deserts of Central Asia. The Sahara. Table-lands and dry plains of Mexico and the adjoining regions of the United States. The influence of the winds. Dry winds. Wet winds.

10. Rains Classified.

Constant rains. Their locality. Cause. Periodical rains. Their locality. Annual movement of the Equatorial Calm Belt. Periodical rains in the Old World. Cause. Rainy and dry seasons. Variable rains, locality of.

11. Excessive and Deficient Rainfall.

Regions of excess. Of deficiency. Causes. Irrigation in dry regions.

TEST QUESTIONS.—Dews are heavier in the fall than in spring; why? Why are they heavier on low grounds than on the adjacent hills? You have noticed that the clouds in spring take on a different appearance from what they have in winter; can you think of any reason for it? To which class do thunder-clouds belong? How is it that clouds change their forms so constantly? Why should there be more rain on land than at sea?

VI. HAIL, SNOW, AND GLACIERS.

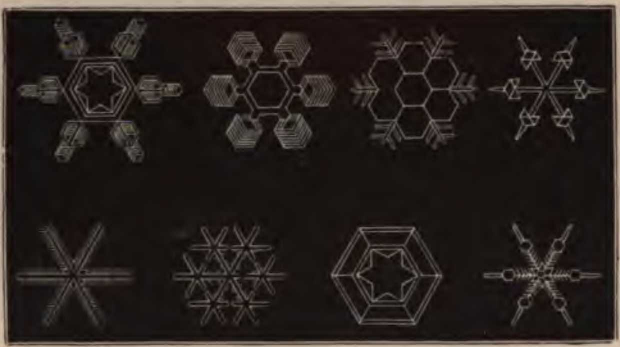
1. Hail.—Moisture, descending through the cold upper regions of the atmosphere, is sometimes frozen, and becomes hail or snow.

When examined carefully, hail has been often found to consist of concentric layers of ice, encasing one another like the layers of an onion.

In size, hailstones vary. Occasionally they are as large as marbles, or even hens' eggs, so that severe hailstorms occasion very great damage to crops.

The formation of hail is not well understood. The sudden ascent of moist air into the cold upper regions of the atmosphere is, probably, the most common cause of this phenomenon.

Glaisher, in his balloon ascension, found the temperature, at the height of three miles, 18° Fahr., at four, 8°, at five, −2°. The temperature at the surface was 59°.



SNOW CRYSTALS.

2. Snow.—The moisture that falls from the clouds, frozen in flakes, is called snow. When examined, it is usually found to consist of exquisitely formed crystals, which are generally in the shape of a six-pointed star. [See illustration.]

Snow rarely occurs within the limits of about 30° north and south latitude, except on high mountain tops. It is naturally more abundant as we approach the poles. It is also in general more abundant where the climate is inland, than where it is maritime. Paris has, on an average, 12 snowy days in the year; St. Petersburg, 170.

Snow is perpetual, however, even at the equator, upon all heights greater than about 3 miles above the sea-level. The line above which snow is always found is called the *snow-line.* [See small map on p. 105.] It varies in altitude from many causes.

Whatever tends to elevate the temperature of any locality, tends also to elevate the snow-line. Hence a low snow-line means a cold climate. While at the equator the snow-line is 16,000 feet high, at the Straits of Magellan it is only about 4,000, and in Norway about 5,000.

THE OFFICES OF SNOW are two-fold: (1) it protects the earth and the crops planted in late autumn from the intense cold and the injurious effects of frost. Sometimes there is a difference of 40° between the temperature of the ground a little below the surface, and that of the snow that covers it; (2) the vast quantities of snow that fall on the great mountain ranges, as the Himalayas, the Alps, and the Rocky Mountains, serve as perpetual feeders of the rivers.

The quantity of snow that falls on an extensive range of mountains, such as the Alps, is very great. Agassiz observed a fall of fifty-seven feet in six months at the Hospice of Grimsel, and observations during twelve years near the Pass of the Great St. Bernard showed an annual snow-fall varying from twelve to forty-four feet. It has been estimated that the average annual snow-fall on the Alps amounts to sixty feet, which is equivalent to six feet of water.

AVALANCHES.—A large part of the snow, as already stated, gradually melts and flows through the river-courses to the sea. Other, although much smaller portions, descend the mountain slopes into the valleys as *avalanches.* The snow is loosened from its bed by the warmth of the advancing season, and plunges down the steep declivities with frightful velocity. Sometimes the very echo of a loud word is enough to disturb the overhanging mass and hurl it into the valley below.

Many instances are on record of the appalling destruction wrought by this scourge of the Alps, whole villages having been overwhelmed, and hundreds of lives destroyed by a single avalanche. Thick forests are the best protection against danger from this source, and in former times the penalty of death has been adjudged against any who should destroy a single tree of the protecting barrier.

3. Glaciers (from the French *glace,* ice,) are vast masses of ice filling mountain valleys. Imagine a river descending a ravine to be dammed up so as to fill the ravine completely, and then to be frozen solid. This will give you some conception of a glacier.

FORMATION.—The process by which glaciers are formed appears to be as follows: the snow that falls in elevated ravines gradually becomes compacted in structure, owing to its partial melting by the sun's rays, and from the pressure of its own weight.

If we should follow one of these ravines downward, we should find the snow growing more and more solid under our feet, until we reached the snow line. Below this line we should find the compacted snow turned to ice. Following the course of the ravine we should observe that the ice mass filled it from side to side and terminated at length among the gardens and pastures of the lower valleys, a stream of water gushing forth from its cavernous extremity. *This is a glacier of the first rank.* Others again, smaller in extent, and containing comparatively little ice, never reach the lower valleys. These are *glaciers of the second rank.*

THE MER-DE-GLACE.—(From a Photograph.)

The compacted snow reaches about to the snow-line, and is called the *névé* (nā-vā). The névé is in general about half the density of ice, or more than three times that of snow.

Motion of the Glaciers.—Solid and immovable as these mighty seas of ice appear, they are really in motion. Long before glacier motion was suspected by scientific men, it had been known to the mountaineers that blocks of stone lying upon the surface of glaciers moved slowly downward.

A large number of carefully conducted observations have been made, which prove not only that the glacier has motion, but that its motion closely resembles that of a river. It is swiftest in the centre, and slower, owing to the friction, near the sides and bottom. Notwithstanding this movement, the termination of the glacier retains about the same position from year to year, because it is melted away as fast as it moves downward.

Rate of Motion.—The rapidity of the motion of a glacier depends upon the season of the year, the size of the glacier, and the inclination of its bed. The motion is more rapid in summer than in winter, in the day time than at night, and in a large and deep glacier than in a small one.

The average rate per year, for glaciers of the first rank in the Alps, is not far from 100 yards; for glaciers of the second rank, not more than one quarter of the same amount.

The middle of the Mer-de-Glace was found by Tyndall to move 20 to 33 inches a day in summer. The rate is about half as much in winter.

The following figures express in yards the motion, during one year, of a row of poles set in a straight line across the glacier of the Aar, by Prof. Agassiz:

5. 20. 48. 55. 62. 64. 67. 69. 79. 68. 64. 54. 47. 39. 21. 11. 1.

The central part, therefore, moved about 80 yards a year.

The great glaciers of Greenland and Alaska move at the rate of 60 to 100 feet a day.

Some glaciers, notably that of the Rhone, tell their own tale of their movement down the valley. On their surface concentric curves are seen bulging toward the lower end of the glacier. These show, as clearly as a line of stakes, the more rapid movement of the central portion of the glacier.

Owing to the slowness of the glacier motion, what is now the upper end of the glacier may be a century or more before it gets to the foot of the mountain.

Theory of Glacier Motion.—Various theories, none of which is in all respects satisfactory, have been advanced to account for glacier motion and the accompanying phenomena. The first thing to be accounted for is the motion itself. Two causes for this may be given: (1) gravitation; (2) expansion within the glacier. It is probable that both these take part in producing the motion.

Gravitation, or the weight of the glacier, would naturally draw the mass down the slopes of the valley.

Expansion within the glacier needs explanation. When the water from the melted surface of the glacier percolates downward into the interior of the mass, it encounters a temperature of 32° Fahr. It freezes and of course expands. Its expansion must necessarily take place in the direction of least resistance, *i.e.*, toward the lower end of the valley. When we recollect that freezing water will burst a plugged bombshell [see p. 43], we can readily see that a force will be developed by the water freezing in the glacier-mass quite sufficient to aid materially in urging forward its enormous weight.

Regelation.—The facts must now be considered, first, that the ice of a glacier accommodates itself to the shape of its enclosing valley very much as a river does to its channel; and, second, that after fracture its parts reunite. These phenomena are explained by what is known as regelation or second freezing. If we pound a mass of ice into fragments and then moisten the broken surfaces, the fragments will readily freeze compactly together again.

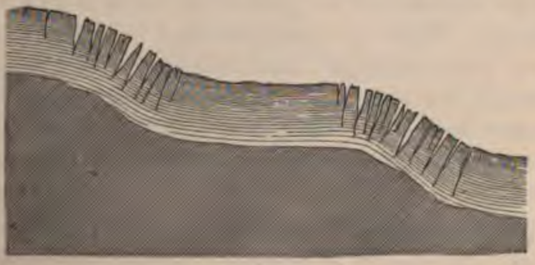
This is what occurs in a glacier. In passing through narrow gorges it is crushed and broken, and in gliding over steep irregularities in its bed it is cracked and splintered. The lower parts break away from the upper, and fissures of great depth called *crevasses* are formed, as shown in the following illustration.

But after the ice has been thus broken and splintered or sundered by crevasses, it reunites and forms one compact mass. The crevasses admit warm air, and their walls are perhaps slightly thawed, or, the ice on the top of the glacier being melted, water trickles down and moistens the fractured surfaces. In this condition the mass of fragments is compressed by its confining valley-walls, the sundered portions are brought together again, and regelation occurs.

Effect of pressure on melting point of ice.—It appears from recent experiments that under pressure ice melts at a lower temperature than 32° Fahr. If a wire weighted at each end be caused to cut through a block of ice, water will be seen flowing round the wire, while, in the cut behind or above the wire, it is found to be frozen. This experiment has an important bearing upon the phenomena of glacier motion. Pressure is obviously exerted by certain portions of the glacier upon others, especially when the glacier is squeezed within gorges. If this pressure develop heat enough to bring the melting point of ice to 28° instead of 32°, it is easy to see how the onward movement of the glacier would be facilitated by reason of its partial liquefaction.

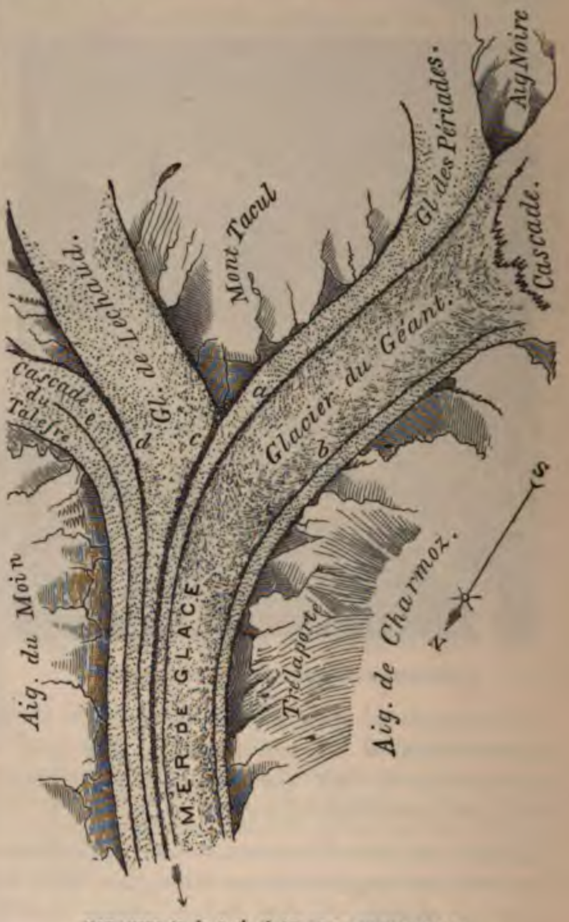
MORAINES. — The rocks and *débris* brought down from the slopes of the ravine by the action of the frost and by avalanches, accumulate along the sides of the glacier. Hence a dark band of earth and stones may be seen upon each side, varying according to the character of the rock encountered. These bands are called *moraines.* Occurring at the sides they are called *lateral moraines.*

At the confluence of two glaciers, the moraines which skirt the two sides that join are united, and form a *medial moraine.* If another glacier unites with this again, a second medial moraine is formed in the same manner.



CREVASSES.

NOTE.—In the accompanying cut it will be seen that the Glacier du Géant unites first with the Glacier des Périades, and from their junction the dotted line shows the medial moraine formed from the right moraine of the Géant glacier and the left moraine of the Périades. Where the glacier thus reinforced receives the Glacier de Léchaud, another medial moraine is formed; and a third where the Talefre adds its tributary stream. By the junction of these is formed the Mer-de-Glace.



MORAINES (a, b, c, d, e) OF THE MER-DE-GLACE.

The earth, stone and boulders brought down on the glaciers form, at the lower end of the glacier, where the ice melts and leaves them, immense deposits, called *terminal moraines.*

TRANSPORTING POWER OF GLACIERS.—The existence of what are known as "boulders" and * "rocking stones," or "erratics," as they are also called, is explained by the transporting power of glaciers. Such stones have been portions of ancient moraines. And therefore, from the presence of boulders, we argue that in former ages glaciers moved over certain regions where they are now unknown. A belt of country extending from the Baltic to the Black Sea has been strewn, by glaciers and drift-ice of a former period, with boulders that were rent from the Scandinavian Mountains.

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* "Rocking stones" are large blocks of stone which are so balanced that they may be rocked by a push. They are called "erratics," *i. e.* wanderers, because found at a distance from their original site.

A similar process is still going on in the transportation of boulders southwardly from the Arctic cliffs. They are borne by the glaciers of Greenland to the shores of Baffin Bay, and thence to the Banks of Newfoundland, where, meeting with the Gulf Stream, they are dropped by the ice, and deposited on the bottom. Thus these banks are formed.

ICE AND BOULDERS.

GLACIERS AS RIVER SOURCES.—The glacier, as it imperceptibly glides down the mountain, is melting all the time, and the traveller upon its rugged surface may hear, far down in its creviced depths, the sound of running water, which gathers volume from a thousand trickling streamlets, and at last issues forth, the never-failing source of some noble river.

The Rhine, the Rhone, and many tributaries of the Danube and Po, spring from glaciers in the region around the St. Gothard; and every one of the hundreds of glaciers found among the Alps nourishes some stream, that it may fertilize the land and cheer the heart of the husbandman. The Ganges, in India, leaps out from under a glacier, a torrent forty yards in width.

DISTRIBUTION AND SIZE OF GLACIERS.—Glaciers of enormous size are found in the Arctic regions. Probably most of the valleys in Greenland and Spitzbergen are occupied by them.

The grandest glacier region of the temperate zone is that of the Himalayas. The glacier of Bépho, in one of the valleys of the Karakorum range, is 36 miles in length—about four times as long as the Mer-de-Glace—and covers hundreds of square miles in area. Many others in the same region are of nearly equal extent.

It is estimated that the total number of glaciers in the Alps is about 500, and that the surface constantly covered by snow, *névé*, and ice is more than 1,000 square miles. The thickness of the Alpine glaciers is believed to vary from 200 feet to 2,000. The Pyrenees and the Scandinavian mountains contain glaciers of the second rank. Large ones exist in the Caucasus.

In the New World, Greenland and Alaska have glaciers far surpassing in magnitude those of the Old World. The Humboldt Glacier, in Greenland, is more than sixty miles in breadth, three hundred feet deep, and of unknown length. Glaciers of large size are found upon Mt. Shasta, and upon Mts. Rainier and Tacoma. The Andes, except in Patagonia, are destitute of them.

4. Icebergs.—The glaciers of the polar regions are not melted into rivers like those of temperate latitudes. Their lower extremity, therefore, is pushed out into the sea, and mountain-like masses are broken off from time to time and borne away by ocean currents. These are called *icebergs.*

DISTRIBUTION.—On the polar side of 55° south, the sea, all the way round the earth, is studded more or less thickly with icebergs. [See Isothermal Chart, pp. 72, 73.]

During his Antarctic voyage in 1841, Sir James Ross sailed 450 miles along an unbroken barrier of ice. It stood 180 feet out of the water, and was aground in water 1,500 feet deep.

Admiral D'Urville fell in with one off the Cape of Good Hope 13 miles long and 100 feet high. I have met with them myself as near the equator as 37° south latitude. Indeed, icebergs enough come from the unexplored Antarctic regions to stud an area as large as the continent of Asia; for navigation is endangered there by ice throughout an area of not less than 15,000,000 square miles.

On the north side of the equator icebergs are found only in the Atlantic; never in the Pacific Ocean. They drift out from their nurseries in the polar regions with the cold currents which bear them southwardly until they disappear in the warm waters of the Gulf Stream. They frequently lodge on the Banks of Newfoundland, where they greatly imperil navigation.

TOPICAL ANALYSIS.

VI. HAIL, SNOW, AND GLACIERS.

- **1. Hail.**
  - Size of hailstones. Formation.
- **2. Snow.**
  - Limits of snow-fall. Of perpetual snow. Offices of snow. Amount of snow-fall in mountain regions. Avalanches. Cause. Destructive effects.
- **3. Glaciers.**
  - Formation. Glaciers of the first rank. Second rank. *Névé.* Motion. Resemblance to that of a river. Circumstances affecting rapidity of motion. Rate of motion. How determined. Indications of motion on the surface. Theory of motion. Causes of motion. Regelation. Cre-

vasses. Moraines. Origin. Lateral, medial and terminal moraines. Transporting power of glaciers. Former glacier regions. Glaciers as river sources. Distribution and size of glaciers. Himalayan region. The New World.

4. Icebergs.

Origin and character. Distribution.

Test Questions.—How can so cold a substance as snow be a protector from cold? Why should the snow-fall be so much greater on mountains than elsewhere? Do you know of any other phenomenon similar to avalanches in character and destructive effects? At the rate of 100 yards per year, how long would it take ice to move from the upper to the lower end of a valley six miles long? If there are four moraines on a glacier how many smaller glaciers have united to form it? Icebergs project about 1-9 out of the water; how deep will one extend which projects 100 feet, the size being the same above and below the water?

VII. ELECTRICAL AND OPTICAL PHENOMENA.

1. Atmospheric Electricity.—The atmosphere in clear weather is almost invariably in a positively electrified condition; the surface of the earth, in relation to the air, appears to be always negative. In cloudy and stormy weather this rule does not hold good, and in thunder-storms the electrical conditions of earth and air sometimes change entirely; and this may occur with instantaneous rapidity. It is to be remembered, however, that the conducting power of the earth renders very difficult the detection of its true electrical condition at any given point.

The electricity of the atmosphere manifests itself chiefly in lightning and auroras.

Lightning is of three kinds—zigzag, sheet-lightning and ball-lightning.

Zigzag lightning consists of flashes passing between two bodies of air or clouds, or between a cloud and the earth, the two being in opposite electrical conditions. The electricity takes the path of least resistance, and since different portions of the air have different conducting powers, the pathway of the lightning naturally becomes zigzag. Sometimes the flash is forked.

ZIGZAG LIGHTNING, FROM A PHOTOGRAPH.

Sheet-lightning, frequently called heat-lightning, appears as a glow of light illuminating vast clouds and even large areas of the sky. It is probable that this kind of lightning is the reflection of the lightning of some distant storm.

Ball-lightning appears in the shape of globular masses of fire, which explode with violence. It is of rare occurrence.

Thunder is considered to be occasioned by the sudden rushing together of the portions of the atmosphere that have been divided by a flash of lightning. It is not often heard at a greater distance than fourteen miles. Occasionally, however, in level regions such as the prairies, it may be heard at a very much greater distance.

The flash is seen instantaneously, because light travels about 188,000 miles in a second. The sound requires about five seconds to travel one mile. Hence, if after seeing the lightning, we count the number of seconds, or pulse beats, until we hear the thunder, it is easy to ascertain how near the flash has been to us.

Thunder-storms are usually very local, but this is not always the case. That which accompanied the "bursting" of the May monsoon in 1848 extended over an area of 600 miles in length and fifty in breadth.

In general the electricity does not pass from the air to the earth, but only from one portion of the atmosphere to another. When a discharge to the earth does occur, the effects are often very destructive. The strongest trees, if struck, are rent and stripped of their branches, the sap being suddenly converted into steam, and an explosion actually taking place. Animals and men who are struck are almost always killed.

Distribution.—Thunder-storms are much more frequent in warm than in cool climates. They occur in that section of the torrid zone known as the belt of Constant Precipitation almost every day in the year.

The Aurora Borealis, or Northern Lights, is a luminous appearance often observed, as the name implies, in the northern heavens. In the southern hemisphere the same phenomenon is called *Aurora Australis.*

The form of the aurora varies greatly. Sometimes it is simply an arch of light spanning the sky near the horizon, with quivering streamers of white, green, or crimson light, shooting fitfully to the zenith. Sometimes mere masses of colored light are observed. At times the whole heavens are flushed.

Nature.—The aurora is simply an electrical phenomenon. The following facts establish the probability of this.

(1) The delicate shades of rose, and purple, and violet, which characterize the more brilliant auroras, can be produced by passing the electric spark through the partial vacuum of a Geissler tube or the very high vacua employed in the experiments of Mr. Crookes, of England.

It has been computed from observations of a large number of auroras, that the beams never approach nearer to the earth's surface than forty-five miles, and sometimes extend from it to the distance of more than 500. Hence the atmosphere in which the auroral light is displayed is very attenuated, like that through which the electricity is passed in the experiments alluded to.

(2) Direct evidence of the electric character of the aurora is found in the effect produced upon telegraph wires during an auroral display. The aurora has sometimes caused the instruments to work, just as though it had been a battery. The effect is similar to that occasioned during a thunderstorm, but usually of less intensity.

ST. ELMO'S FIRE.

(3) The magnetic needle, also, is disturbed during auroras in a degree corresponding to the brilliancy of the display. During the splendid aurora of September 2d, 1859, the declination of the needle, at Toronto, changed nearly 4° in half an hour. This aurora extended round the globe, for it was seen in Europe and North America, and in the Sandwich Islands, and it indicated its presence in Northern Asia, where the sky was cloudy, by magnetic disturbances.

Distribution.—Auroras are more frequent as we approach the poles. Within the tropics they are almost unknown. Thus their law of distribution is just the reverse of that which governs the distribution of lightning.

In North America the zone of greatest frequency lies between 50° and 62° north latitude. Here the displays are of almost daily occurrence. North and south of this belt the annual number rapidly decreases, being on the average about ten in latitude 40°, and the same in latitude 78°. In Europe the zone of greatest frequency lies between 66° and 75° north latitude.

ST. ELMO'S FIRE.—In storms at sea the masts and yards of the ship are sometimes tipped with balls of electric light. The superstitious sailor trembles with awe at the sight of them, believing them to be the souls of the dead.

They are due to electricity passing without noise, when the clouds are low, between the clouds and the tips of the spars of the ship.

2. Optical Phenomena.—The most important of all the optical phenomena connected with the atmosphere is also the most common. It is *the diffusion of light. This is brought about by reflection and refraction.* By the former, light is propagated from particle to particle of the atmosphere. By the latter, it is retained above the horizon when the sun has actually gone down, and it is bent into the atmosphere before he has actually risen above the horizon.

Refraction and reflection give rise to the exquisite variety of colors which deck the morning and evening sky. They also occasion the less frequent phenomena of rainbows, halos and mirage.

The Rainbow is an arch of colored light which spans tne heavens during a storm. It is seen only when the sun is shining at the same time that rain is falling. The descending drops separate the white sunlight into its elementary colors.

Halos are rings of prismatic colors round the sun or moon. They are really circular rainbows, and are probably due to the refracting power of the small ice-crystals composing cirrus clouds.

Mirage. Another effect of refraction and reflection is commonly called *mirage.* It is often observed in the desert. Distant villages seem under its influence to be near to the spectator, or to be suspended in the heavens above. Sometimes the traveller thinks he is approaching a pool of sparkling water, and hastens to quench his thirst, when he finds that he has been pursuing a mirage.

Mirage is also observed at sea, distant ships being seen elevated above their true position, or even inverted in the air.

TOPICAL ANALYSIS.

VII. ELECTRICAL AND OPTICAL PHENOMENA.

1. Atmospheric Electricity.

- Electrical condition of air and earth compared. Character. How manifested.
- Kinds of lightning. Zig-zag lightning. Cause of its broken and forked course. Sheet-lightning. Ball-lightning. Cause of thunder. At what distance audible. Distance of the flash. How computed.
- Area and distribution of thunder-storms. Destructive effects of lightning.
- Aurora Borealis and Australis. Form and appearance. Nature. Reasons for considering it an electrical phenomenon. Distribution. St. Elmo's fire.

2. Optical Phenomena.

- Diffusion of light. How caused. Other effects. Description of the rainbow, halos and mirage.

TEST QUESTIONS.—If the thunder is heard in three seconds after the flash, what is the distance of the discharge? Why does the rainbow show seven colors?

TOPICAL ANALYSIS FOR REVIEW.

- **Physical Properties of the Atmosphere.**
  - The Atmosphere. Composition. Uses of ingredients.
  - The weight of the air.
    - Evidences that the air has weight.
    - Amount of pressure. Effect on the boiling point.
    - Causes of variation in pressure.
      - Effect of changes of level.
      - Effect of changes in weight of air.
    - Height of the atmosphere.
    - Change of density with height.
- **Climate.**
  - Climate.
    - Main Elements.
    - Modifying Causes.
  - Distance from the equator.
    - Effect on annual temperature.
    - Climatic contrasts.
  - Distance from the sea.
    - Insular climates. Causes which moderate them.
    - Inland climates. Reasons for their extremes.
  - Prevailing winds and ocean currents.
  - Height above the sea-level. Reasons for effect of elevation. General rule.
  - Isothermal lines.
    - Relation to parallels.
    - Zones of temperature.
- **Winds and Circulation of the Air.**
  - Causes of winds. Heat. Moisture.
  - General Circulation.
    - Location of constant ascending currents.
    - Causes which complicate circulation.
    - Classification of winds.
  - Trade winds.
    - General character. Direction.
    - Cause of westward trend.
  - Variable Winds.
    - Locality.
    - Counter trades. Origin. Proofs. Direction.
    - Polar winds.
  - The calm belts. Equatorial. Calms of Cancer. Capricorn.
  - Periodical winds.
    - Land and sea breezes. Benefits of.
    - Monsoons. Cause. Effect. Minor monsoons.
    - Other periodic winds.
      - Desert winds.
      - Mountain winds.
  - Offices of winds.
- **Storms.**
  - General Description. Cyclones. Classes.
  - Cause of storms. Cause of spiral movement.
  - Laws of storms.
    - Direction of the whirl.
    - Forward motion of the storm.
    - Calm at the centre. Causes of low barometer at the centre.
    - Irregularity of land storms.
  - Value of storm laws. Areas of storms.
  - Whirlwinds and Tornadoes.
    - Difference between these and hurricanes and typhoons.
    - Destructive effects.
    - Dust whirlwinds. Waterspouts.
  - Distribution.
  - Weather forecasts. Great storms in the United States.
- **Moisture of the Air.**
  - Evaporation.
    - Conditions under which it takes place.
    - Causes which increase it.
      - Temperature. Pressure.
      - Dryness. Winds.
  - Condensation and Precipitation.
    - Forms of water derived from vapor.
    - Cause of precipitation. Dew-point.
  - Formation of dew.
    - Effect of clouds.
    - Difference in quantity on various substances.
  - Fog. How formed. Illustrations.
  - Clouds.
    - Various forms.
      - Cirrus. Cumulus. Stratus.
      - Cirro-cumulus. Cirro-stratus. Cumulo-stratus
      - Cumulo-cirro-stratus.
    - Velocity of cloud movement.
    - Height. Offices.
  - Rain.
    - Cause of rainfall. Distribution.
    - Regulators of rainfall.
      - Mountains. Various examples.
      - Deserts. Examples.
      - Winds. Dry and wet winds.
    - Classification.
      - Constant. Locality. Cause.
      - Periodical.
        - Locality. Rainy and dry seasons in New and Old Worlds.
      - Variable. Where found.
    - Excessive and deficient rainfall.
      - Regions of excess.
      - Of deficiency. Causes.
- **Hail, Snow and Glaciers.**
  - Hail. Size. Formation.
  - Snow.
    - Limits of snow-fall. Of perpetual snow.
    - Offices. Amount of snow-fall in mountain regions.
    - Avalanches.
      - Cause.
      - Destructive effects.
  - Glaciers.
    - Formation. Glaciers of the first rank. Second rank.
    - Motion.
      - Circumstances affecting rapidity of motion. Average rate.
      - Theory of Motion.
        - Causes.
        - Regelation. Crevasses. Effect of pressure.
    - Moraines. Origin. Kinds.
    - Transporting Power.
      - Origin of boulders.
      - Former glacier regions.
    - Glaciers as river sources.
    - Distribution and size.
  - Icebergs. Origin. Distribution.
- **Electrical and Optical Phenomena.**
  - Atmospheric Electricity.
    - Character. How manifested.
    - Kinds of lightning.
    - Cause of thunder. Distance of the flash.
    - Distribution of storms. Destructive effects.
  - Aurora Borealis and Australis
    - Form and appearance.
    - Nature. Distribution.
  - St. Elmo's Fire.
  - Optical Phenomena.
    - Diffusion of light. How caused.
    - Other effects.
      - Color of clouds. The rainbow.
      - Halos. Mirage.

PART V.

LIFE.

I. RELATIONS BETWEEN PLANTS AND ANIMALS.

1. Life. — In the foregoing pages we have treated of the land, the water, and the air. These are known as the inorganic or lifeless portions of the earth. We come now to that which is organic. This term (derived from the Greek *organon*, an instrument) signifies possessed of *organs* or instruments adapted for doing certain things, *e.g.*, lungs for breathing, hands for handling, feet for walking. It is therefore used as equivalent to *living.*

Of living things there are two grand divisions, plants and animals ; or, as they are often comprehensively called, Flora and Fauna.

In Physical Geography we have to consider, first, the relation of each of these to the other; and secondly, their distribution and its causes.

2. Mutual Dependence of Plants and Animals.—The relations between the plants and animals of the world are such that neither could exist without the other. Each prepares what the other requires.

OXYGEN REQUIRED BY ANIMALS.—The various forms of animal life require a constant supply of that element of the air known as oxygen. Even the fishes, though they seem to breathe water, really extract oxygen from the water by means of their gills; for in water a certain amount of atmospheric air is always present.

When taken into the bodies of animals, oxygen undergoes a change which renders it not only unfit for breathing again, but actually poisonous. It forms a compound called carbonic acid gas. This gas is also produced in the process of fermenting beer, and if, as sometimes occurs, a man falls into the vat, it is almost certain death to him. In an atmosphere containing large quantities of it, therefore, animal life would not be possible.

Some arrangement is required to remove such a dangerous ingredient from the atmosphere. This is accomplished by the various forms of plant life. Let us see how it is done.

OXYGEN PREPARED BY PLANTS.—The leaves of plants have upon their surface a multitude of little pores or mouthlets. Through these the leaves, while the sunshine rests upon them, have the singular property of taking in carbonic acid. In the plant this gas undergoes a change. Its parts, carbon and oxygen, were put together in the body of the animal : they are put asunder in the substance of the plant. The charcoal, which makes a poisonous compound with oxygen, is separated from it, and employed by the plant in building up its massive branches, its beautiful flowers, and its nutritious fruit.

While the plant is thus appropriating, or, as we might say, digesting the carbon of the carbonic acid, it is also permitting the oxygen to escape back into the atmosphere, so as to be inhaled once more by the forms of animal life.

FOOD OF ANIMALS SUPPLIED BY PLANTS.—Again, animals are dependent on plants not alone for what they breathe but for what they eat. This is true, whether they are herbivorous (*grass-eaters*) or carnivorous (*flesh-eaters*). For where there is no grass, or any vegetable production that takes its place, herbivorous animals cannot live ; and where they are not found, carnivorous animals, which feed upon them, cannot exist.

On the other hand, plants are indebted to animals for the preparation of that invisible food (carbonic acid gas), upon which they so largely depend, and from a portion of which they build up their forms of solidity and beauty.

PLANTS AND ANIMALS, MUTUAL CHECKS.—Again, plants and animals may be regarded as checks upon one another. A certain proportion of each is required to keep uniform the composition of the atmosphere. If there were too many animals, there would be too much carbonic acid. If there were too many plants, there would be too much oxygen.

The plants absorb the carbon, and throw off oxygen into the atmosphere ; the animals take in oxygen and give out carbon. Thus the one counteracts the excessive action of the other.

INTERVENTION OF THE WINDS.—But the plants that throw out oxygen and the animals that take it up again are often far removed from each other. How is it conveyed from the plants which throw it out to the animals which consume it?

To effect the needed interchange and to keep the air well mixed is one of the offices of that wonderful system of winds of which you have learned. They give circulation to the atmosphere; they bear off the excess of gases from places where they are not wanted, and deliver them for use in other parts of the world where they are needed.

TOPICAL ANALYSIS.

I. RELATIONS BETWEEN PLANTS AND ANIMALS.

1. **Life.**

   Organic and inorganic nature. Flora and fauna. Points with regard to them which are considered in physical geography.

2. **Mutual dependence of Plants and Animals.**

   What animals require for respiration. Change of this element in the process. Effect of the change. Dangerous product of respiration, how disposed of. Oxygen prepared by plants. Food of animals supplied by plants. Plants and animals, mutual checks. Intervention of the winds.

TEST QUESTIONS.—What is the principal thing that plants take up by their roots? Aside from their use in furnishing oxygen, name some of the plants that are directly useful to man. Name some that are indirectly useful.

II. RANGE OF PLANTS AND ANIMALS.

1. General Facts.—It is a familiar fact that the same kinds of plants and animals are not found everywhere. Some forms are widely distributed, others are restricted to very narrow limits. The region within which any plant or animal is found is commonly called its *geographical range*. The dandelion and buttercup blossom even amid the glaciers of Greenland. The orange, the date, and banana grow only within or near the tropics. The gigantic water lily called the Victoria Regia has been found only in the basins of the Amazon and Orinoco.

VICTORIA REGIA.

The camel's thorn is peculiar to the desert. It is too hard for other animals to feed on, but it supplies the camel with food on his journeys. Man converts it to his use also. Its roots strike deep, and it has the faculty of collecting a supply of moisture even amid the parched desert. The Arab makes an incision in the plant, near the root, and inserts a watermelon seed and covers it up. The seed sprouts, and the vine becomes a parasite, producing a melon of delicious flavor.

2. Range Dependent on Climate.—Certain conditions render it possible or impossible for the various species of living forms to exist. Of these conditions by far the most important are temperature and moisture.

The peculiar plants and animals of the torrid zone would obviously die, if placed amid the cold of the Arctic circle; while it is equally certain that the polar bear and his associates would become extinct, if they were exposed to the scorching heat of the tropics.

Illustrations from Geology.—The early geological history of the globe furnishes striking illustrations of this principle. The entire assemblage of animals that we now find upon the earth did not simultaneously spring into existence. Those species first appeared which were suited by existing climatic conditions. Low forms of animal life prevailed at first, and then higher and higher successively, until such conditions arose as were favorable to the life of man, and then, at length, his creation took place.

Many, moreover, of the animals that once abounded have entirely disappeared. Their existence is attested only by fossil remains. Lynxes, bears, and hyenas once roamed over the fields of England, and crocodiles swarmed in its rivers; huge mastodons, larger than the modern elephant, flourished on what are now the banks of the Hudson, and browsed amid the forests of Siberia. Their tusks are dug up at the mouth of the Lena and upon the islands of New Siberia, in such quantities as to form an article of regular commerce, under the name of "fossil ivory." The climatic conditions favorable to their existence have ceased, and their race has therefore become extinct.

MODIFICATIONS BY CLIMATE.—It would follow as a natural conclusion from the fact that plant and animal life are largely dependent on physical conditions, that changes in these conditions should bring about changes in the plants and ani-

THE THREE ZONES.

mals affected by them. Such we find to be the fact. Modifications of a very extraordinary nature can be effected by varying the "environment" of a plant or animal, and allowing the new environment to be permanent during a sufficient length of time. Many of our most valuable food plants have been thus transformed. The grains in general are believed to have been originally wild grasses.

Our own Indian corn presents a very interesting illustration of climatic modification in a vegetable form. In the South it often attains the height of 12 to 15 feet. As we advance northward through its belt of cultivation its height diminishes, until, on the northern edge of the belt, it is not usually more than about 5 feet high. Again, the appearance and quality of its grain have been singularly modified. It is a familiar fact that we have a number of varieties, field-corn, sweet-corn, pop-corn, with white, yellow, brown, and even black grains.

The common nasturtium in tropical countries is a perennial tree; farther north it is dwarfed and becomes a shrub; while in still higher latitudes it is a vine that lives no longer than a single season.

Similar illustrations might be given of the modifications of *animal forms* by changes in their physical conditions. The Shetland pony and the race-horse came from one original stock. The terrier, the greyhound, and the mastiff had a common parentage.

3. Zones of Vegetation.—Since the extent of *the geographical range of plants depends mainly on temperature and moisture,* it follows that the surface of the earth may be divided into zones of vegetation. These will correspond more or less closely with the zones of temperature. They will of course be defined not by lines of latitude, but by lines of heat, or isotherms.

The principle of division is this, that within belts or zones having a certain average annual temperature, certain vegetable growths will flourish; beyond the limits of such zones these characteristic forms disappear, and others are found which are suited by the prevailing temperature. Thus each zone has its characteristic forms of vegetable growth.

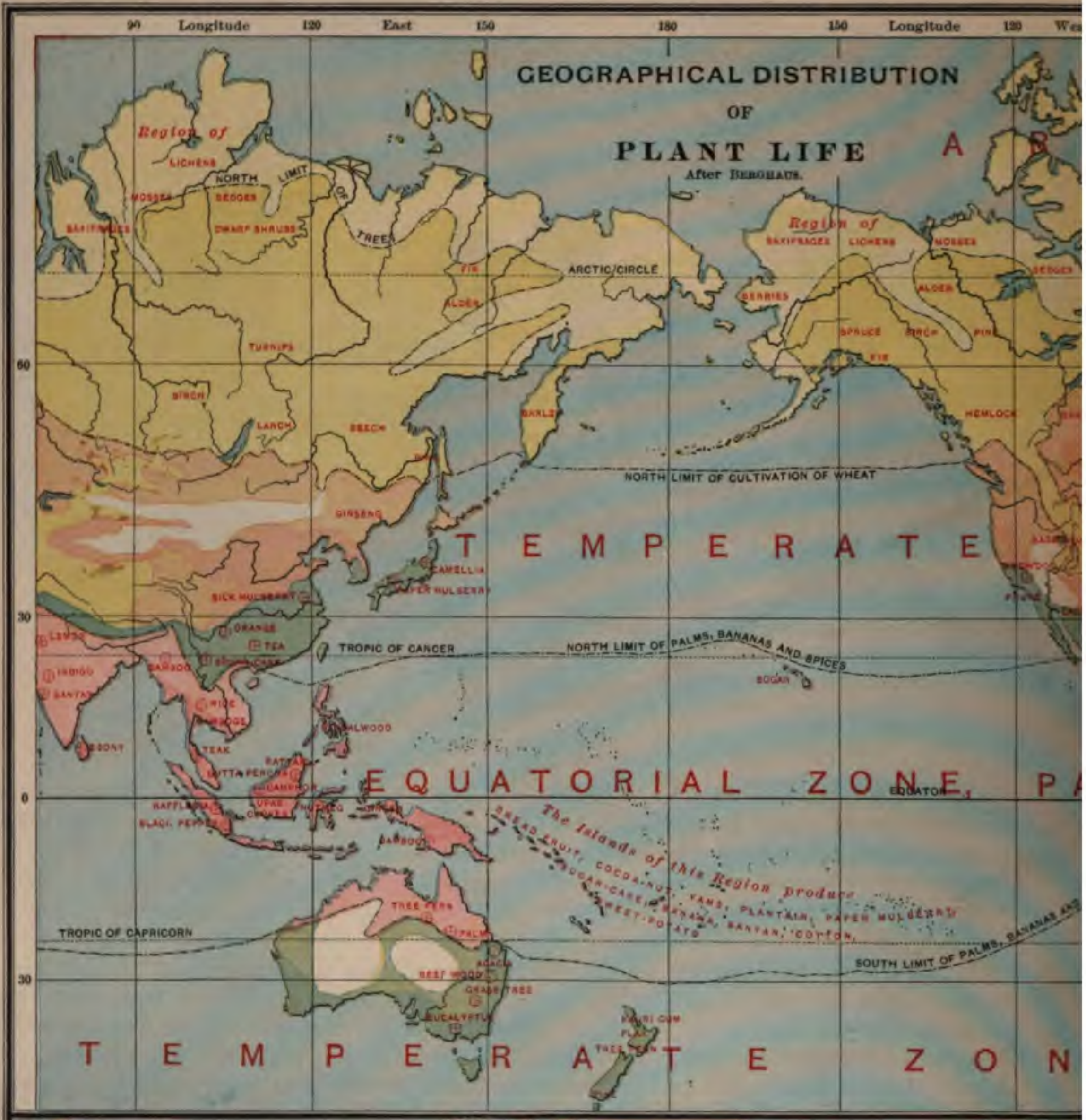
NOTE.—In naming the zones of vegetation we borrow the terms employed in the ordinary division by lines of latitude, always remembering, however, that the signification of the terms does not remain exactly the same.

HORIZONTAL ZONES.—The surface of the earth may be divided into the following horizontal zones of vegetation: (1) an equatorial zone; (2) two temperate zones; (3) two polar zones.

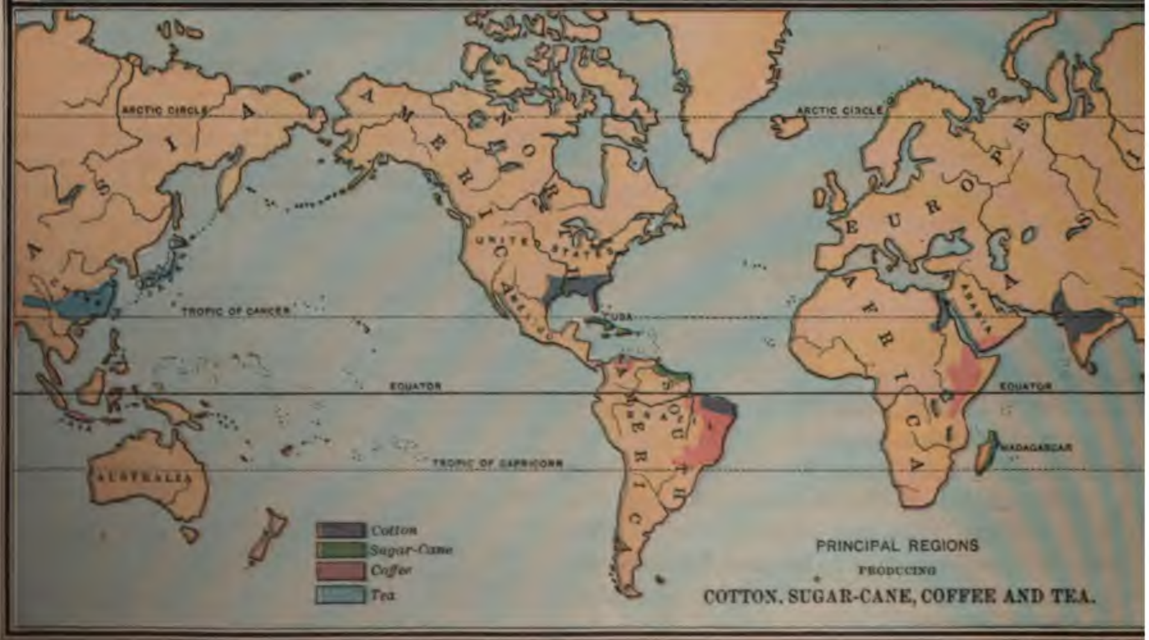
The Equatorial Zone extends north and south of the equator, and is bounded by the annual isotherms of 70° Fahr. It is the zone of greatest heat and most abundant moisture, and consequently of most luxuriant vegetation.

The characteristic growth of this belt is that of the palms. The trees do not lose their leaves in winter.

The Temperate Zones extend northward and



GEOGRAPHICAL DISTRIBUTION
OF
PLANT LIFE
After BERGHAUS.



PRINCIPAL REGIONS
PRODUCING
COTTON, SUGAR-CANE, COFFEE AND TEA.

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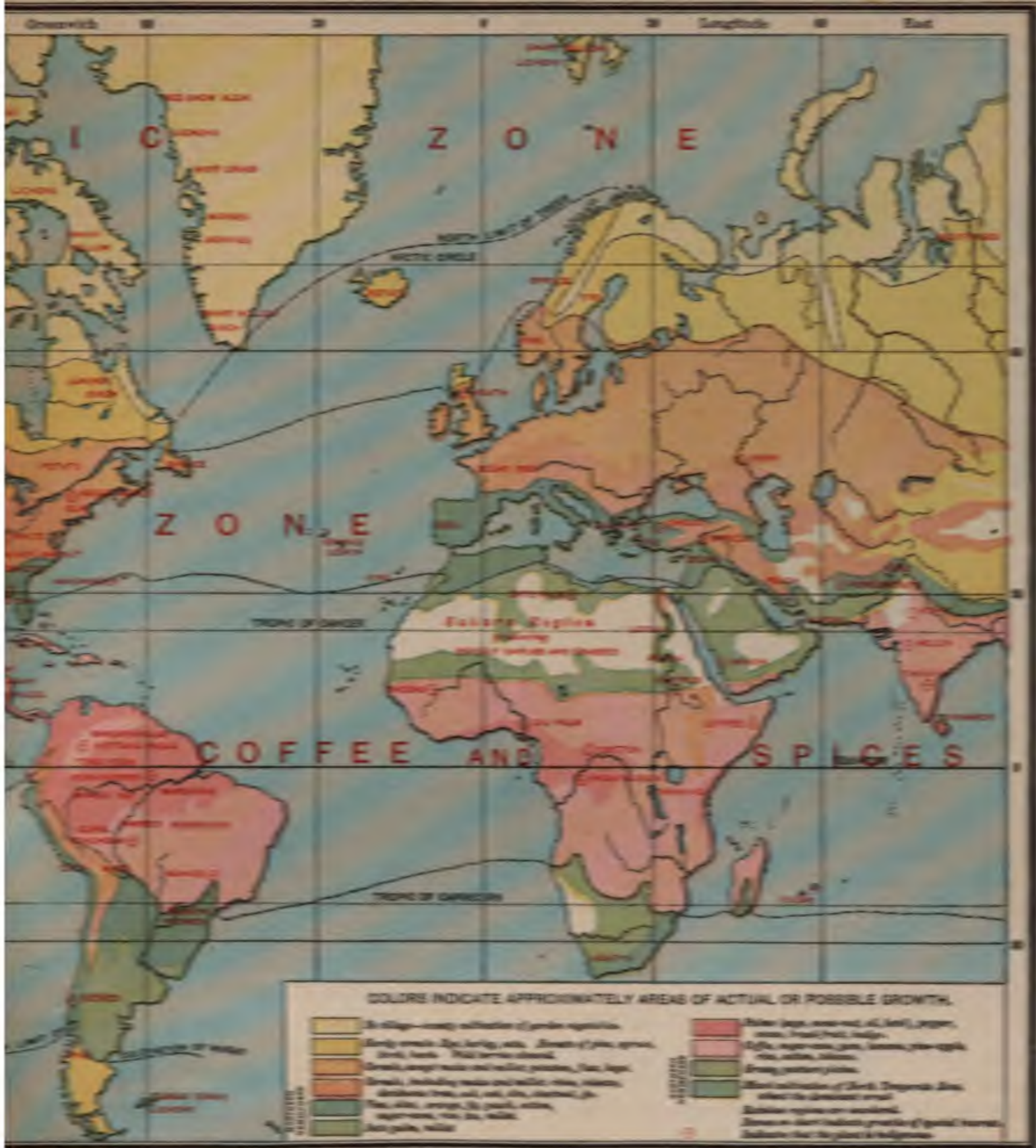
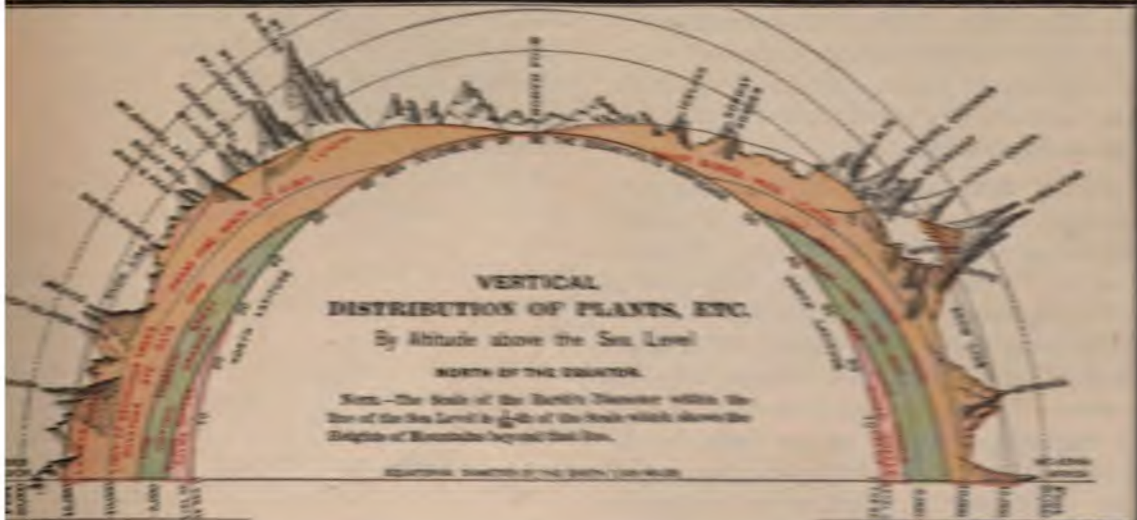


COLORS INDICATE APPROXIMATELY AREAS OF ACTUAL OR POSSIBLE GROWTH.



VERTICAL
DISTRIBUTION OF PLANTS, ETC.
By Altitude above the Sea Level

NORTH OF THE EQUATOR.

Note.—The Scale of the Earth's Diameter within the line of the Sea Level is [illegible] of the Scale which shows the Heights of Mountains beyond that line.

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QUESTIONS ON THE CHART OF PLANT LIFE.—Into how many zones of vegetation is the surface of the earth divided upon the chart? Zones, how defined?

Trace the line of north limit of trees. What vegetable products are found north of that line?

What cereals grow farthest north? What grains are grown in Norway and Sweden? In India? The United States?

On what portions of the American continent is rice grown? In what parts of Asia? Trace the limits of palms, bananas, and spices.

Where is coffee cultivated? In what continent is it indigenous? Tea? (See small map on the left of the chart.) In what localities do you find the sugar cane? Cotton? What are the indigenous products of China?

Where is the mulberry indigenous? What use is made of the leaves of this tree? Where are the silk mulberry regions? What singular trees has Australia? South America? What are the native regions of the bamboo?

Name some plants or trees which are indigenous in more than one region. Can you explain how this should be? Name some plants peculiar to the Islands of the Pacific.

At what height above the sea can potatoes be cultivated? In latitude 10°? In latitude 50°?

southward of the equatorial, and are bounded by the isotherms of 32° Fahr. Here the tropical palms disappear, or are replaced by dwarfed representatives of the family.

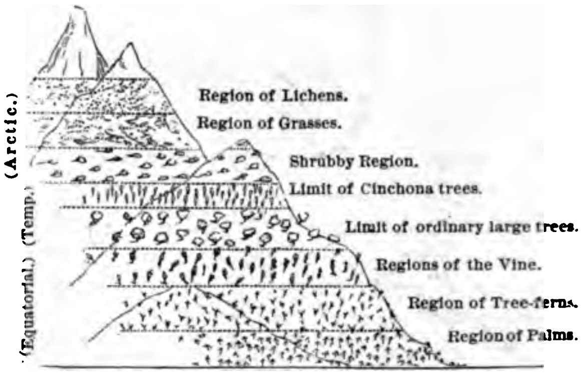
The characteristic forms are those of the deciduous forest trees—that is, those which lose their leaves in autumn and renew them again in spring. The oak, the chestnut, and others which belong to our own forests, are familiar examples of these.

The colder parts of these zones are marked by the abundance of conifers (pines, larches, spruce and juniper trees).

The Polar Zones extend north and south from the temperate. Within them the average annual temperature is not higher than 32°, and in many portions it is below 5°. The warmer parts of these zones contain vast forests of spruce, pine and larch. The colder portions are characterized by the growth of dwarfed birch, alder and willow trees. But beyond certain limits trees wholly disappear, and only the lowest forms of plant life, (mosses and lichens) remain.

VERTICAL ZONES.—Since, by ascending sufficiently high, we can pass, even in equatorial regions, through every variety of climate, torrid, temperate and frigid, it is clear that there must be vertical as well as horizontal zones of vegetation.

On the lower slopes of the Andes, for example, we find regions of palms and bananas, tree-ferns and vines. These correspond to the zone of equatorial vegetation. Higher up we encounter the deciduous trees of the temperate zone. Still farther up we enter a region closely resembling that of the Arctic zone : the conifers are the pre-ling type, while the deciduous trees are represented by shrubs and dwarfed specimens. Near the snow-line trees of every kind disappear, and mosses and lichens are the only forms of vegetation that can support the perpetual cold.



VERTICAL ZONES OF VEGETATION.

4. Range of Food Plants.—It will be of interest to consider the geographical distribution of those plants that are of the greatest importance to man. Of these, the grains or cereals, as they are called (barley, rye, wheat, Indian corn, rice, and millet), deserve attention first. Certain of them have, of all plants, the widest geographical range, and thus furnish a striking instance of provident care in that terrestrial economy which is as benign as it is beautiful.

Barley is cultivated in Europe as high as 70° north latitude, and on the Asiatic table-lands at an elevation of 13,000 feet.

Rye will grow in all regions between 67° north and south latitude.

Wheat has a range almost equal to that of rye. It ripens in North America as far north as latitude 55°, and in Europe, owing to the influence of the Gulf Stream, as far north as lat. 64°. In Mexico and the Andean region its culture begins at the height of about 2,500 feet and is successful as high as 10,000. Upon the Himalayas it is cultivated as high as 12,000 feet above the sea.

Indian Corn will grow and ripen in the open air, from the parallel of 45° or 50° north to the corresponding parallel south. Its range embraces two-thirds of the earth's surface. In the torrid zone neither wheat nor Indian corn do well at the sea-level, though they produce finely on the mountain-sides.

Millet is the most prolific of the cereals. It is adapted better than any other to the vicissitudes of a tropical climate. In Egypt, Arabia, Turkey, and Italy it is an important article of food, and in India it, and not rice, is the staple food grain.

Nearly allied to the cereals as an article of diet is the *potato*. It has a range almost equal to that of barley. It is probably a native of Chili or Peru, but will grow in Iceland.

In the low, damp, and hot portions of the equatorial region, wheat and corn are replaced by rice and the banana, mandioca, and the bread-fruit.

Rice.—The geographical range of rice is limited by the parallels of 45° north and 35° south. This belt covers more than half the surface of the earth. Rice delights in low and swampy ground, and is the chief cereal cultivated in China and Japan. It is the principal article of food for one-third of the entire human family.

The Banana, indigenous in the regions of inter-tropical America, is, as an article of food for the masses, what rice is to the Hindoo, the potato to the Irish, and wheat to the European. An acre of ground planted in bananas requires less cultivation and yields more abundantly than any other food-plant. Humboldt estimates the yield to exceed that of the potato 44 times, and that of wheat 133 times. The banana flourishes 4,000 feet above the sea.

Mandioca or Cassava is a native of South America. It is also extensively grown in Africa and other tropical regions. Its large turnip-like root, dried and grated, is the food of a large part of the population of South America.

Bread Fruit is characteristic of the islands of the Pacific. Its fruit, represented in the cut, furnishes the natives with food somewhat resembling bread.

The *Sugar-cane*, so far as we know its history, seems to have been a native of India or China. It grows in the warm latitudes of every continent.

BREAD-FRUIT.

5. Beverage Plants.—The chief plants which yield beverages, tea, coffee, and cocoa, are grown in warm regions; *tea* in China and Japan, India and Ceylon; *coffee* in Southern Asia, Central Africa, and the tropical portions of North and South America. *Cocoa* is a native of the tropical regions of North and South America.

6. Spices and Narcotics.—The geographical range of the spices, such as cinnamon, nutmeg, ginger, pepper, cloves, allspice, and pimento, is narrow. It is confined to a few degrees north and south of the equator. The East Indies are specially the region of the spices.

NUTMEG.

The important narcotics, tobacco and opium, are natives of warm regions, but their geographical range extends into the temperate zones.

7. Plants used for Clothing.—The principal plants which are used for textile fabrics and clothing are cotton, flax and hemp.

Cotton, the most important of them all, will grow and mature well at moderate heights, anywhere between the parallels of 37½° north and south. This belt being 75° of latitude broad, and extending entirely round the earth where its circumference is largest, gives for this plant a geographical range that embraces more than half the earth's surface.

The United States, Brazil, India, and Egypt are the chief cotton-growing countries.

Flax and *hemp* delight in the climates of the temperate zone, and are brought to their greatest perfection between the parallels of 25° and 50° north.

8. The Medicinal Plants, such as yield sarsaparilla, jalap, castor-oil, quinine, gums, and balsams, are almost all indigenous to the torrid zone.

Foremost among them stands the cinchona, from which quinine is obtained. It is a native of the eastern slopes of the Andes, flourishing in a belt that extends through Bolivia, Peru, and Ecuador, from 3,000 to 9,000 feet above the sea-level. It has been successfully acclimatized in the East Indies.

9. Useful Trees.—The ornamental and dye-woods, such as mahogany, rose, sandal, and logwood, are confined to the torrid zone. The oak, walnut, chestnut, maple, ash, with pines, firs, and cedars, belong to the cooler latitudes.

The geographical range of the oak extends from the tropics to the verge of the frigid zone. The timber trees of the temperate zone are replaced in the torrid by the teak and bamboo.

10. The Flora of the Sea.—The flora of the sea differs from that of the land in color. It is less inclined to green. The plants of the sea are brown and yellow, pink and purple, green, orange and violet, with all intermediate shades.

The vegetation of the sea has, like that of the land, a vertical and a horizontal distribution. Both are determined mainly by the temperature of the water, and the nature of the sea bed.

In the deepest parts of the ocean nothing but microscopic forms of vegetable life of the simplest kind (called *diatoms*) occur. The smaller algæ or sea-weeds scarcely exist below the depth of 300 feet; the larger are not found deeper than about 60 feet below the surface. The horizontal range of many marine plants is co-extensive with the sea. Others, like land plants, have limited ranges.

ALGÆ.—Among the most interesting kinds of algæ are the Macrocystis Pyrifera, the D'Urvillæa Utilis, and the Gulf Weed.

The *Macrocystis Pyrifera* measures 700 feet in length. This weed is like a cord. It attaches itself to the rocks, and grows from the bottom in the littoral waters of many countries, and especially along the northwest coast of America.

Few, if any, forms of vegetation have a wider geographical range than this weed. After all traces of plant life on the land have ceased, as you approach the poles, it is still found flourishing in the water.

The *D'Urvillæa Utilis* grows in the waters of the Falkland Islands and adjoining regions. The surf often twists it into cables several 100 feet long and as thick as the human body. This, like the Macrocystis Pyrifera, fastens itself to the rocks, in stormy waters, with such tenacity that sometimes, in the attempt to tear it away, large boulders are brought up adhering to its roots. It is used as food in Chili.

Plants of this species surround Kerguelen Land with such a tangled mass, that row-boats find it difficult to get through it. The Straits of Magellan are so thick with these weeds that they fouled the rudder, and so entangled the propellers of the first steam vessels that passed through these waters, as seriously to interfere with the navigation.

Gulf Weed.—Among the most widely distributed forms of marine vegetation is the Gulf Weed (*fucus natans*). It is not known whether it grows at the bottom, or near the surface of the sea. I have always found it afloat, living and growing, but without any sign of roots. It lies so thick in the Sargasso Sea, as completely to hide the waters in many places and give the sea the appearance of a drowned meadow.

11. Distribution of Animals. — Animals, like plants, require a certain temperature, for the maintenance of their life. Furthermore, no animal except man can inhabit regions in which nature does not spontaneously provide for it suitable food; and hence the fauna of every country is dependent on its flora. For these two reasons the distribution of animals, like that of plants, depends mainly upon climate.

HIPPOPOTAMUSES.

ZONES OF ANIMAL LIFE.—In view of this fact it is usual to divide the earth's surface, in relation to its fauna, into the same equatorial, temperate, and polar zones which have been indicated in treating of the distribution of plants.

The Equatorial Zone is characterized by the abundance of its forms of animal life. It is the zone of lions, tigers, rhinoceroses, elephants, camels, crocodiles, poisonous serpents, and birds of the most brilliant plumage.

The Temperate Zones, on the other hand, are distinguished by the number of their useful animals, such as the ox, cow, horse, sheep, and goat. The eagle, turkey, and pheasant are among the birds. In coloring, the animals of temperate regions are far less brilliant than those of the equatorial zone.

In *the Arctic regions* (for of the Antarctic we know little or nothing) we find the fewest species, although the individuals are numerous. The reindeer, musk ox, white and brown bear, wolves, white foxes, and sables are the chief land animals. The seal, walrus, and whale sport in the waters. Reptiles are unknown.

Zoological Regions.—It is obvious that any division of the earth's surface into zones characterized by peculiar fauna and flora is necessarily far from exact. Although the distribution of life on the globe is mainly dependent on climate, it is not so altogether.

For, in the first place, many species over-lap, being found in more than one zone. The dog is the companion of man in every zone; sugar-cane grows in both torrid and temperate regions.

And in the second place, however alike in climate different portions of the earth's surface may be, they do not necessarily have the same flora and fauna. The isothermals of the United States traverse also the Empire of China. Yet there are marked differences between the forms of plant and animal life which characterize the two regions. The isothermal of 68° passes through Australia, South America, China, and the Gulf region of the United States. But the vegetation and animal life of these regions are strikingly diverse.

From these considerations scientific men have been led to seek some division more in harmony than that of zones with existing facts. That proposed by the eminent naturalist Sclater, and more exactly defined by Mr. Wallace, seems to be the most satisfactory thus far devised.

According to this division the surface of the earth is made up of *six regions*. Each of these has certain forms of life which are peculiarly its own and not found elsewhere, although it may have many species in common with other regions. The following are the names of the regions with their leading characteristic forms. [See map on next page.]

(1) *The Northern Old World Region* includes all of Europe, all temperate Asia north of the Himalayas and northern Africa down to the Tropic of Cancer. Here we find the bear, wolf, deer, horse, cow, and camel, the wild goats, the eagle, the corncrake, and bustard.

Peculiar to this region are almost all the known species of goats and sheep, moles and dormice; and among birds the nightingale, magpies, and almost the entire group of pheasants.

(2) *The Ethiopian or African Region* embraces Africa south of the Tropic of Cancer, southern Arabia, and the island of Madagascar. Here we lose sight of certain forms familiar in the Northern Old World Region, bears, deer, moles, and true pigs; and camels and goats, except in the desert regions, are equally wanting.

Peculiar forms are the gorilla, chimpanzee and baboon, the hippopotamus and giraffe, the guinea-fowls, most of the weaver birds, and the secretary bird.

Madagascar and the neighboring islands, though classed as parts of the Ethiopian region, have a fauna peculiar to themselves. This insular sub-region is one of the most wonderful in the world from a zoological point of view. It is especially characterized by the abundance of lemurs (nocturnal animals somewhat resembling monkeys, but very small); while most of the groups in which Africa is especially rich—apes, lions, leopards, giraffes, antelopes, and elephants—are wholly wanting. Some of the birds are entirely unlike all other known species.

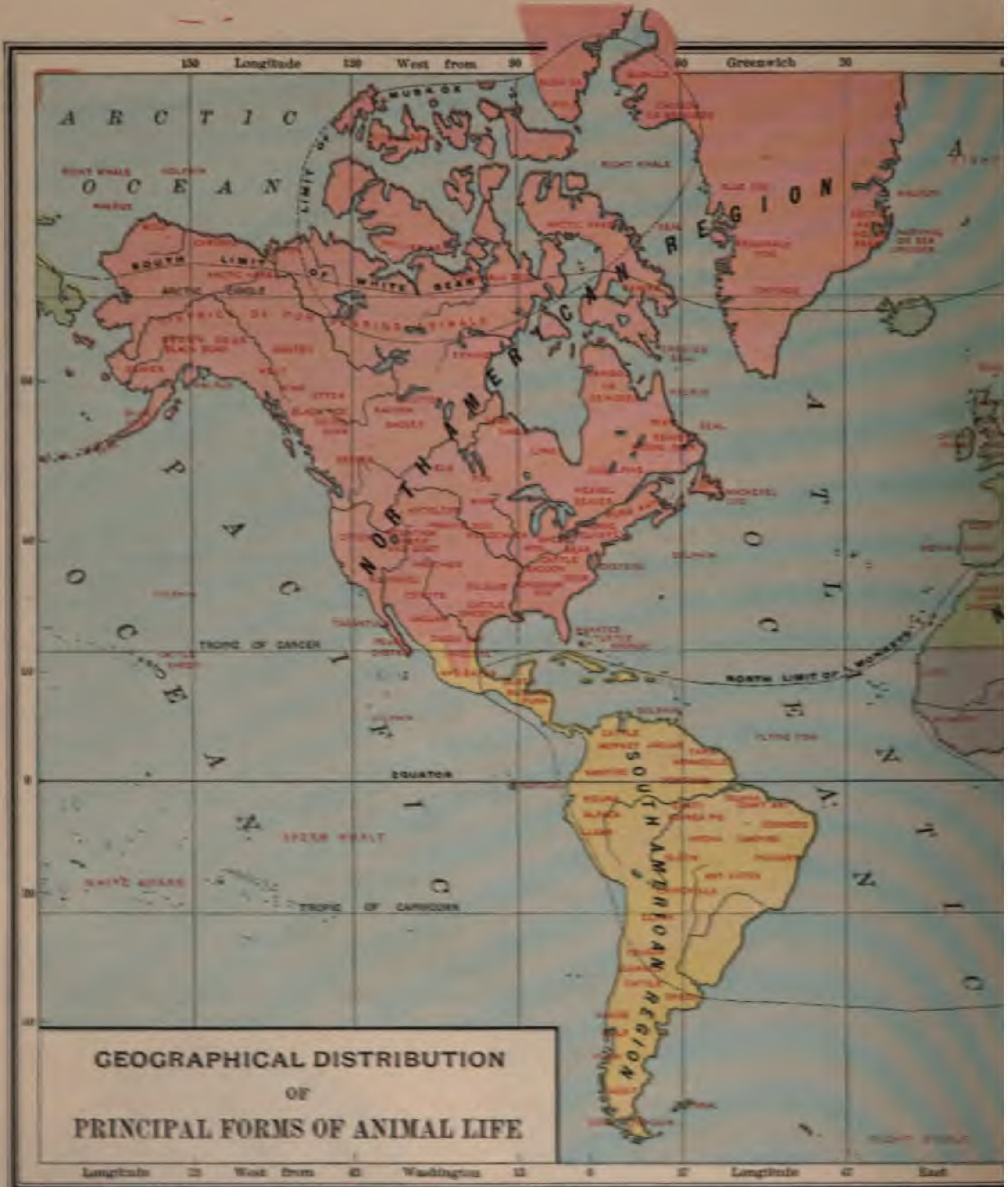
(3) *The Indian Region* comprises India, Indo-China and the East Indian Islands as far as the Strait of Macassar.

Peculiar to this region are the ourang-outang, the tiger, the honey-bear, the civet and flying lemurs; and among the bright-feathered birds, the argus pheasant, the peacock, the trogon, and the curious little tailor birds.

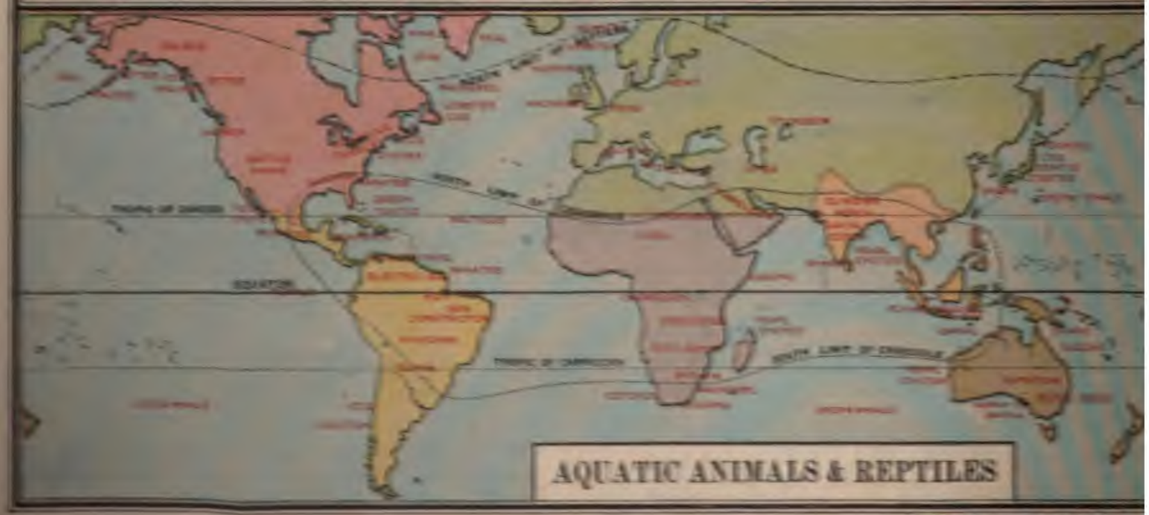
(4) *The Australian Region* consists of Australia, New Zealand, Polynesia, and those of the Malayan islands that lie east of the Strait of Macassar.

AUSTRALIAN ANIMALS.

This region has a fauna of marked peculiarity. It is notable for the absence of forms elsewhere almost universal. The higher mammalia of other regions are replaced by mammals (such as the duckbill) that lay eggs; and by marsupials (*i.e.*, animals with a pouch for holding their young).



GEOGRAPHICAL DISTRIBUTION
OF
PRINCIPAL FORMS OF ANIMAL LIFE



AQUATIC ANIMALS & REPTILES

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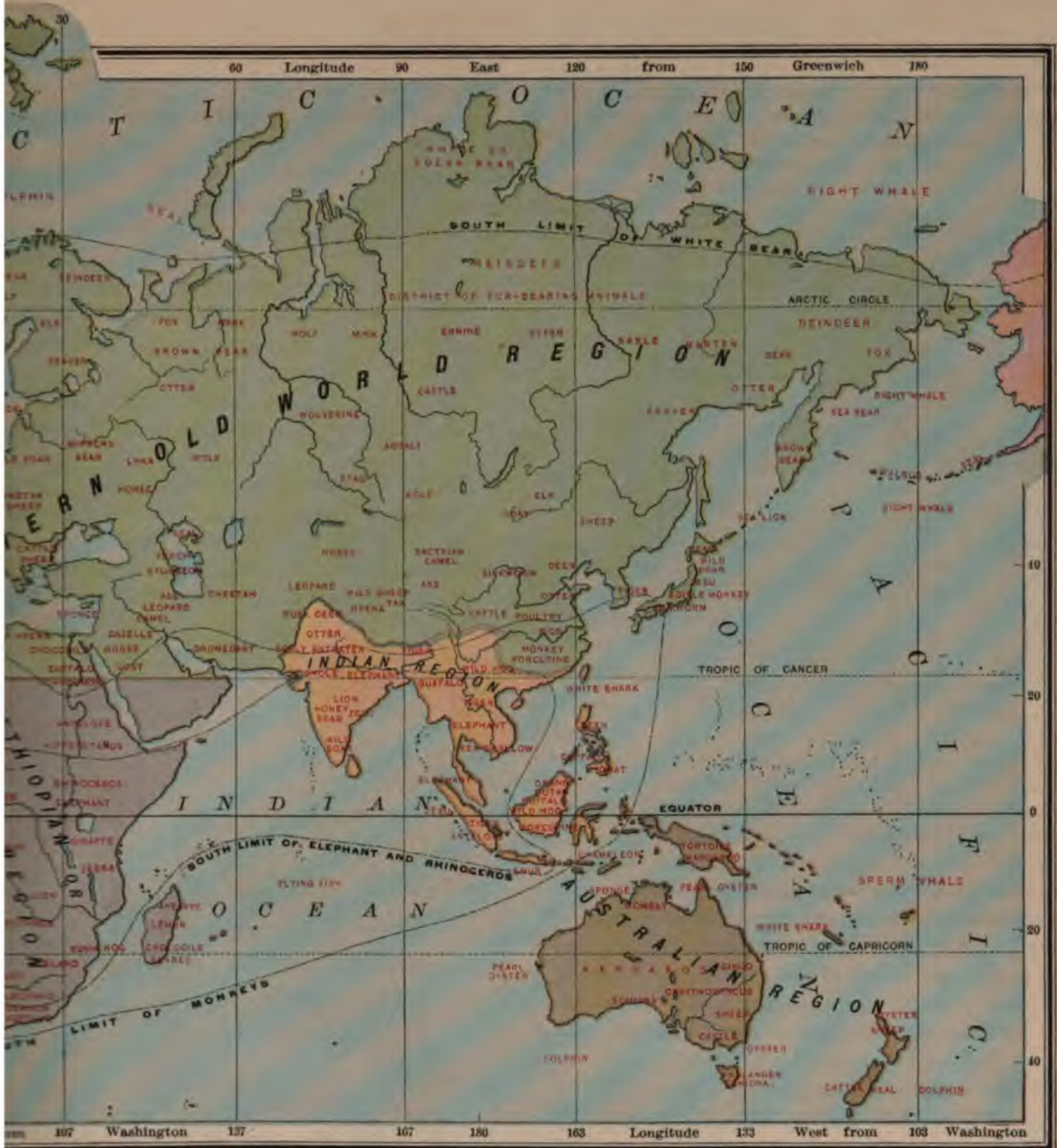

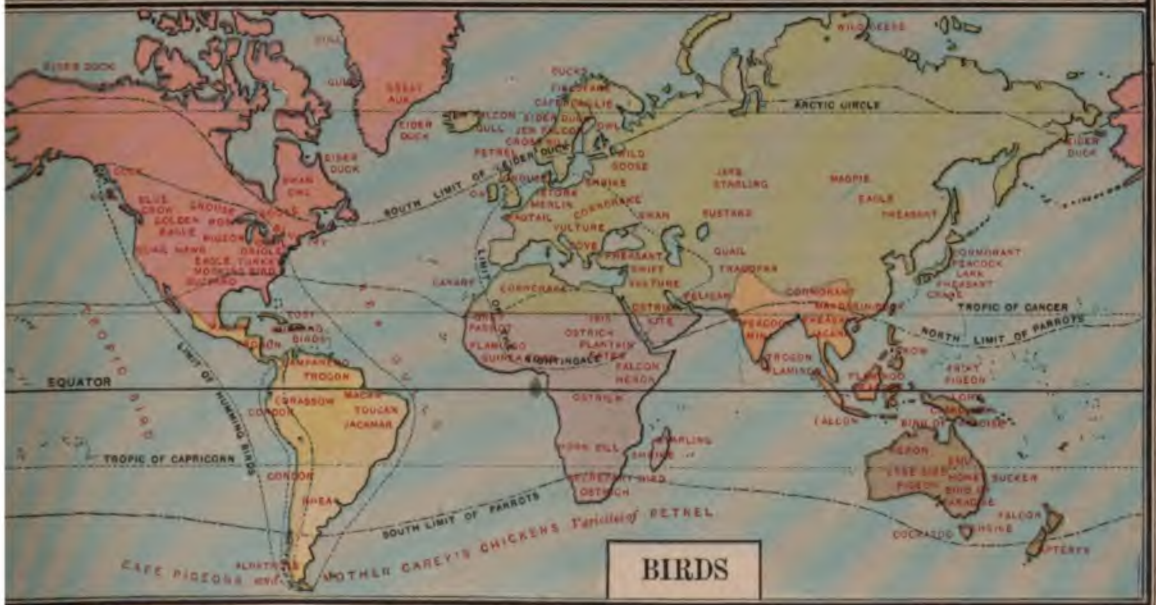

BIRDS

NIVERSITY PUBLISHING CO., NEW YORK.

Questions on the Chart of Animals.—Into how many regions of animal life is the surface of the earth divided on the map ? Of what does each consist ? Of what regions is the reindeer an inhabitant ? Where is the moose deer found ? Describe the limits of the Polar bear. What other animals are in the North Frigid Zone.

What fur-bearing animals are found in North America ? In Europe and Asia ? Are the fur-bearing animals found in cold or in warm countries? Can you name any exceptions to this rule ?

What are the limits within which monkeys are found ? To what regions do they belong? Where are baboons found? In what regions are found the elephant and rhinoceros? The tiger? The camel?

Where are gorillas found? Porcupines? Yaks? Hippopotamuses? Walruses? Seals? What animals are peculiar to the Australian region? What curious animals are found nowhere but in Madagascar?

In what waters is the sperm whale found? the right whale? What are the limits of crocodiles? Mention localities in which the cod is found. The mackerel. Shark.

Where are pearl oysters found? In warm or cold waters? Are the seal and the walrus found in cold or in warm water?

What are the limits of the nightingale? The regions of the eider-duck? Of humming-birds? Of parrots?

Does the duck seem to be a native of low or of high latitudes? How is it, in this respect, with the albatross? The gull? To what region does the mocking bird belong? The ostrich? The bird of paradise? The condor and vulture?

Can you explain why the kangaroo and emu are not to be found in the Indian region?

Of these none are found elsewhere, except the opossum of North and South America. Among the marsupials of Australia are the kangaroo, the tree-kangaroo, and the wombat.

The bird life of this region is rich in handsome and peculiar forms, such as the beautiful bird of paradise, the crimson dory, the lyre bird, the bower bird, the emu, and the cassowary.

(5) *The North American Region* includes the continent and adjacent islands north of the Tropic of Cancer.

The fauna of this area and that of the Old World region present marked dissimilarities. Here we do not find native, the horses, asses, cows, sheep, pigs, hedgehogs, and dormice of the Old World. They are replaced by the bison (nearly extinct), raccoons, opossums (marsupial), prairie dogs, and skunks. The thrushes, wrens, robins, and finches are represented by new families.

Among animals peculiar to this region are the grizzly bear, the pouched rat, the mocking-bird, the blue-jay, the blue crow and the rattlesnake.

It is hardly necessary to say that many Old World forms have been introduced.

(6) *The South American Region* embraces South America and that portion of North America and the outlying islands which are south of the Tropic of Cancer.

Of all the regions this is the most remarkable for the fewness of the forms which it contains in common with others. No horse, or ass, ox, sheep or goat is a native of South America. The wild cattle and horses which now roam over its plains and pampas are the offspring of animals introduced by Europeans.

This region is equally remarkable as containing a greater number than any other of forms which are strictly its own. Among these are the sloth, the armadillo, the llama, the alpaca and chinchilla, the blood-sucking vampire bat, the prehensile-tailed monkey,* and the destructive boa-constrictor.

Here alone we find the condors, toucans, todies, rheas, curassows and mot-mots. The forest-clad slopes of the Andes are alive with the murmur of 400 species of humming birds, some of which pass their cheery existence near the limits of perpetual snow.

REINDEER.

12. Range of Draught Animals.—Of special interest is the geographical range of those animals which man employs as draught animals or beasts of burden.

The horse, the ass and the ox, either native or introduced, are found wherever grains and grasses grow. Beyond the limits of these food plants the reindeer and the dog become the draught animals. The reindeer is fitted to browse upon Arctic mosses, and has the instinct of searching for them beneath the snow. He presents one of the most striking cases of an animal adapted to the peculiar conditions of his habitat.

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* Monkeys whose tails are capable of grasping the branches of trees

In the equatorial regions of the Old World we find the elephant serving as a beast of burden; while to the northward, especially in desert regions, the camel and dromedary are employed.

The cushioned foot of the camel enables him to tread firmly upon the shifting sands of the desert, while his capacity for carrying an extra supply of water adapts him wonderfully for journeying through its dry and thirsty wilds.

In South America, where, to traverse the continent, the traveller has to scale the snowy heights of the Andes, there—and not in North America, where the mountains have gaps that the buffalo can cross—was found the *llama,* the camel of the New World, the only beast of burden in use among the native Americans at the time of the discovery of the continent.

The llama, with the alpaca and vicuna, which are different species of the same genus, have their habitat along the edge of the snow-line on the Andes, where the atmospheric pressure is not more than eight or ten, instead of fifteen, pounds to the square inch.

This diminished pressure of the atmosphere has very marked effects upon both man and beast. To one from the lowlands, respiration, in these elevated regions, is difficult. Mules are used for the transportation of merchandise between these places and the seaboard, but never ascend beyond a certain height. At the elevation of 5,000 or 6,000 feet they are met by the llamas of the table-land, and the cargoes are exchanged.

The same wise provision appears in the organization of the llama as in that of the camel. Without these creatures, man, in the early stages of civilization, could neither have crossed the deserts of the Old World, nor scaled the cloud-capped mountains of the New.

Among the fastnesses of the Himalayas, and upon the bleak heights of the plateau of Thibet, the beautiful *yak* serves as a beast of burden. He is to be seen browsing at an elevation of 17,000 feet above the sea. What the camel is to the Arab, what the llama is to the Peruvian, the yak is to the native of Thibet.

CAMELS.

APTERYX.

13. *Limited Range of Some Animals.*—Many animals are confined to a very narrow geographical range by causes that are in some cases quite obscure. The little chinchilla, with its beautiful fur, has its habitat on the Andes, of Chili and Peru, 8,000 to 12,000 ft. above the sea.

The chamois inhabits the belt of the Alps which lies between the trees and the snow-line.

The Cashmere goat, noted for its fine wool, is restricted to the valleys of the Himalayas.

The ostrich of Africa, the rhea of South America, the emu of Australia, the cassowary of Papua, the apteryx of New Zealand, are birds which neither fly nor swim. Their geographical range therefore is very limited. The same was true of the dodo of Mauritius, and the æpyornis of Madagascar.

Animals of limited range are the *most likely to become extinct.* The apteryx is nearly so; the dodo has become so within two centuries; and the æpyornis became so at a very recent period, for one of its eggs (8 times as large as that of an ostrich) was found and brought to Europe in 1851.

Of all animals, none, perhaps, has its geographical range so singularly marked as the *Tsetse fly* of South Africa. Though it is well formed for flight, it never appears to go beyond certain limits. These are marked by no river, hills, or other geographical feature, and yet are so sharply defined by their invisible boundaries, that if a horse crosses them, he is immediately attacked by the fly and killed.

14. Fauna of the Sea.—As with the animals of the land, so with those of the sea—different species have their geographical range, both vertical and horizontal, beyond the limits of which the conditions necessary for their existence are not found. This, however, is less rigidly true with regard to the fauna of the sea than that of the land. It is quite obvious that temperature must be the main element which determines the habitat of marine animals. Other matters, such as the nature of the sea-bottom, have a minor influence.

COD-FISH.

Life of Tropical Waters.—The waters of the tropics, like the shores which they bathe, teem with the greatest variety of animal forms. Many of the fish and crustaceans are decked with colors of surprising brilliancy.

OYSTERS OF DIFFERENT AGES.

The sperm whale delights in the warm waters of this zone, and is most abundant in the Pacific Ocean. Flying-fish, albacore, bonito and sharks are all inhabitants of intertropical seas. Pearl-oysters, also, with corals and sponges, are found in this belt.

Life of Cooler Waters.—In the cooler seas of the temperate and arctic regions we find the greatest abundance of fish that are of value to man. All the famous food-fisheries in the world—those of the cod, the herring, the mackerel, and others—are in the waters of cold currents.

The Grand Banks of Newfoundland, the fisheries of the North Sea, and those of the Pacific coasts of America, China and Japan, all lie within the range of the cold flow from the north. It is to the presence of the cold current along our Atlantic seaboard that our own fish markets owe their celebrity.

The right whale delights in the cold waters of polar seas. Those of the torrid zone are as impassable to him as a sea of flame. So true is this that the right whale of the northern hemisphere and the right whale of the southern are restricted each to his own zone.

MARBLED SEAL.

Although the seal may be found in all latitudes, his favorite haunts are the islands of Alaska, the shores of Labrador and the bays of Patagonia. Other inhabitants of polar waters are the sea-lion, hunted for his fur, and the walrus, for his ivory tusks, which are superior to those of the elephant, and the narwhal, or sea unicorn, whose ivory horn is eight or ten feet in length.

Various depths are suited to various species of marine animals. The reef-building polyp cannot flourish at a greater depth than about 150 feet below the surface. Lower down, in depths so great as 1,500 or even 2,400 fathoms, living forms are found, but they are of a low order—foraminifera, sponges, starfish, and molluscs. The bathymetrical range of such creatures is surprisingly great.

15. Floral Regions.—What may have been in all cases the precise causes which led to the existing distribution of animal life is not merely difficult, but impossible to decide. No doubt the reasons for the absence from South America of every kind of native horse or ass, and the presence of many peculiar forms of life, must be sought in the long past geological history of the continent. To a large extent they must be forever matter of conjecture; and the same may be said of many other exceedingly curious problems that present themselves to the student of this subject.

But whatever the causes in question may have been, we should naturally expect, from the intimate connection of plant and animal life, that the influences which have affected the distribution of the one should have produced a corresponding effect upon the other. In a word, it would seem reasonable that the six regions into which the earth's surface has been found to be divisible on zoological grounds should be not only zoological, but *phytological* or botanical also.

The flora of each region may not perhaps be as distinctly marked as the fauna. There will naturally be much overlapping, many species being very widely diffused, and some being common to all parts of the globe. Still we ought to find some characteristic floral peculiarities in each region. And this we do find.

The *Old World* region is the native home of all the cereals excepting maize, of the apricot, the cherry, the apple, the pear, the olive, the cork oak, and sycamore fig.

The *Ethiopian* region has among its peculiar vegetable forms the baobab, the oil palm, and coffee.

The *Indian* region is characterized by the banyan, the fig, the mango, cinnamon, the gutta-percha and teak trees, and the sweet potato.

The *Australian* region has a flora very distinct from that of all others. The leaves of the trees are of a peculiar bluish-green hue, and strangely present their edges to the sun, arranging themselves vertically instead of horizontally. The eucalyptus or gum-trees, of which there are 400 varieties, are among the loftiest trees in the world. Many are 400 feet high. One monster was felled which measured 480 feet. The beefwood trees are remarkable. Instead of leaves, of which they have none, they have sheaths enclosing their branches. They thus resemble in structure the "horsetail" with which we are familiar.

The *North American* region is the native home of the magnolia, the live oak, the sequoia gigantea (giant trees of California), and persimmon. Nearly 400 species of trees are peculiar to this region.

The *South American* region is distinguished by the multitude of its parasitic forms. Peculiar to it are the cinchona, cacao and cocoa, the manioc, the potato, sarsaparilla, the Victoria Regia, and the passion flower.

TOPICAL ANALYSIS.

II. RANGE OF PLANTS AND ANIMALS.

1. General facts.
Illustrations. Geographical range.

2. Range dependent on Climate.
Illustrations furnished by geology. Modifications by climate. Indian corn.

3. Zones of Vegetation.
How defined. Horizontal zones. Limits and characteristics of each.
Vertical zones. Correspondence of their characteristic vegetation to that of the horizontal zones.

4. Range of Food Plants.
Range of cereals; barley, rye, wheat, Indian corn, millet and rice. Of the potato, banana, mandioca, bread-fruit and sugar-cane.

5. Beverage Plants.

6. Spices and Narcotics.

7. Plants used for Clothing.

8. Medicinal Plants.

9. Useful Trees.
Timber trees of the torrid zone.

10. Flora of the Sea.
Colors, as compared with those of the land flora.
Distribution. Vertical distribution.
Algæ. Interesting forms.

11. Distribution of Animals.
Why mainly dependent on climate.
Zones of animal life. Characteristics and principal animals of each.
Zoological regions. Divisions into zones of life, why not exact. Animal life of the different zoological regions. to what extent distinct.
Northern Old World region. Important animals. Animals peculiar to the region.
Ethiopian region. Peculiar forms. Animal life of Madagascar and neighboring islands.
Indian region. Peculiar animals.
Australian region. For what remarkable. Forms peculiar to it.
North American region. Distinction between its forms and those of the Northern Old World. Peculiar animals.
South American region. For what remarkable Peculiar forms.

12. Range of Draught Animals.
Adaptation of the reindeer, the camel, and the llama, alpaca and vicuna to locality. The yak.

13. Limited Range of some Animals.

14. Fauna of the Sea.
Range of, by what determined. Life of tropical waters. Of cooler waters. Range of the seal. Vertical range of the reef-building polyp. Life at great depths.

15. Floral Regions.
Reasons for coincidence of floral with zoological regions. Plants peculiar to each.

TEST QUESTIONS.—Name some plants distinguished for their wide range. Some animals. What draught animals have the widest range? Does the range of plants tend to increase? Of animals? Is the range of either affected by human agency? Can you give examples? Which of the cereals is produced in the greatest quantity? Which is most largely raised in this country? Which has the wider range, tea or coffee?

III. MAN.

1. Range of Human Habitation.—Man dwells in every zone and at nearly all altitudes. He is literally cosmopolitan. Unlike the irrational animals, he can, to a large extent, overcome the force of external conditions. He can protect himself from the severity of the winter's cold, and maintain his existence amid the snows of the Arctic regions; and on the other hand he can endure the fierceness of inter-tropical heat. Thus his horizontal range is almost unlimited.

He has again, an ample vertical range. The lowest place where men have established permanent dwelling-places is in the valley of the Dead Sea, 1,300 feet *below* the sea. The highest is at the convent of Hanle, inhabited by twenty Thibetan monks, 16,533 feet *above* the sea. These limits include a vertical range of more than three miles.

2. Unity of the Human Family.—Wherever man is found, he presents the same essential features of body and of mind. No such differences sunder men as those which subsist between the horse and the lion, the eagle and the ostrich. The human family is of one blood.

3. Diversity.—Still the heat and cold to which man is habitually exposed, the food which he lives upon, and the physical conditions generally by which he is surrounded will, in the lapse of time, produce certain effects upon his bodily and intellectual organization. Hence we find wide diversities characterizing different portions of the human family. Men differ in color, in feature, in mental and moral peculiarities, industrial habits, social and governmental institutions.

4. Division into Races.—Some ethnologists divide the great human family into three, some into five, others into six or even a larger number of races.

The five great races of mankind, as generally recognized, are the *Caucasian* or white, the *Mongolian* or yellow, the *Negro* or black, the *Malay* or brown, and the *Indian* or red.

THE CAUCASIAN RACE derives its name from the Caucasus range of mountains, because of the tradition that the region traversed by these mountains was the birthplace of the race.

The chief divisions of the Caucasians are: (1) the Indo-European, comprising the Hindoos, Persians, Circassians, Slavonians, Teutons, and Celts; and (2) the Semitic families, of whom the Hebrews and Arabs are the most important.

The term Indo-European is derived from the fact that this division of the race has established itself all the way from India to the farthest bounds of Europe.

Extent. —Nine-tenths of the people of the United States, as well as all the peoples of Europe, except the Lapps, Finns, and Magyars, and the Turks proper, belong to the Caucasian race. Both of the Americas are governed by it. Africa is largely controlled by it. In Asia, it extends from the shores of the Mediterranean, through Arabia and Persia, and along the southern slopes of the Himalaya mountains beyond the banks of the Brahmapootra.

Characteristics.—The Caucasians are the most symmetrical in figure, comely in person, and beautiful in feature, of all the branches of the human family. The numerous divisions and subdivisions of the race vary in complexion according to the region they occupy. The extremes are the Germans with their flaxen hair, blue eyes, and fair skin, and the Hindoos with raven locks, black eyes, and olive-brown or brownish-black skin. The face of the Caucasian is oval, the head ample; the hair full and often curled or wavy.

Intellectual Superiority.—In intellect this race ranks first. With very few exceptions all the leading thinkers of the world have been Caucasians; and without any exception all the great discoveries of recent times have been made by members of this family.

It is the race to which has been assigned the office of civilizing and enlightening the world. Its social habits and its governmental institutions, its educational systems, and its religious views are those which most conduce to the elevation and happiness of mankind.

Wherever the white man establishes himself he speedily becomes dominant; while the communities of other races into which he introduces himself are commonly subjected to a gradual process of extinction.

The Mongolian Race derives its name from the Asiatic tribe of Mongols. The Chinese, Indo-Chinese, Japanese, Thibetans, and Turks in Asia; the Finns, Magyars, and Lapps in Europe, and the Esquimaux of the Arctic regions of North America are branches of this race.

Characteristics.—The color of the Mongolian is olive-yellow. His face is broad, with wide and flattened nose, and small, obliquely set eyes. His hair is straight, coarse, and black. In stature he is somewhat below the ordinary standard of the Caucasian.

In intelligence and moral character he ranks next to the Caucasian.

Branches of the Mongolians, as the Eskimo, are very low in the intellectual scale. Not so the Chinese and Japanese. It is true that, in the past, they have displayed the mental inactivity which marks the Mongolian in general. They remained for ages just where their ancestors had been. A vast change, however, is going on. The recent establishment of a constitutional form of government by the Japanese, and their adoption of many important features of European civilization entitle them to rank among the progressive nations of the world.

The same may be said in a less degree of the Chinese.

Somewhat also must be said in commendation of the native civilization of both these great Mongolian communities. China has had a governmental system, including the feature of promotion by competitive examinations, which has stood the test of ages. Japan too has been a prosperous and well-ordered state for generations of which we have no count.

In religion the Mongolians are generally Buddhists.

The Negro Race is so called from the color of its skin (Latin, *niger*, black). It occupies nearly the whole of the African continent. The hair of the Negro is short and curly; his nose is flat, wide, and upturned; his cheek bones are prominent, and his lips thick.

The moral and intellectual status of the Negro in his native land is low. When brought into contact, however, with the Caucasian race, he shows himself capable of considerable elevation.

The *native Australians*, though classed by some ethnologists as a separate race, may properly be regarded as a branch of the negro family. They are probably the most degraded members of the human species. Before the European settler they are rapidly dying out.

The Malay Race is held by some to be a branch of the Mongolian. Its characteristics are, however, sufficiently marked to entitle it to separate classification.

The Malays occupy a part of Southeastern Asia and most of the islands of the Pacific. The Malay peninsula, Sumatra and Java, Borneo, Celebes, Formosa, the Philippines, New Zealand and the Polynesian Islands, all had this race for their aborigines.

Characteristics.—The members of the Malay race are of medium height, with well-proportioned limbs. Their color varies from olive-yellow to brown or black. Their hair is coarse and black.

Intellectually and morally the Malayan is of a low order. Some of them, however, have a written language and a legal code. They are true sea rovers, and prone to piracy.

The American Indians constitute what some ethnologists designate as an off-shoot of the Mongolian race. At the time of Columbus they had spread all over North and South America.

Some of the better known tribes are the Chippeways, Sioux, Apaches, and Cherokees in North America; the Caribs, the Araucanians, and Patagonians, in South America.

Characteristics.—The American Indian is copper-colored or red, and therefore he is often called the Red man. His hair is black, coarse, and straight, his cheek bones prominent. In person he is tall and lithe. He is remarkable for his endurance of fatigue and his disregard of pain. Intellectually and morally he occupies a medium position among the races of mankind.

The Indian is rapidly disappearing.

Early Civilization.—The Incas of Peru and the Aztecs of Mexico were found in a comparatively high state of civilization by Pizarro and Cortez; and there are, in Central America and the western part of the United States, interesting memorials of a long-forgotten civilization which had its home in those regions.

The Montezumas of Mexico had their halls, their academies and schools, their zoölogical and botanical gardens, their calendar and their monuments. Their capital, at the time of Cortez, vied with the wealthiest cities of Europe.

5. Conditions Favorable to Civilization.—From this brief review of the races it will be seen how powerful has been the influence of physical circumstances upon man. Some portions of the human family have remained hopelessly barbarous. Some have received civilization from others, and some, again, have given birth to a civilization of their own—an *indigenous* civilization. Wherever this last has occurred, it has invariably been neither at the poles, nor in the hot lands of the tropics, but rather in a middle ground between the two. It is here that those conditions

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Questions on the Chart of Races of Men.—Name the regions occupied by the Caucasians. The Mongolians. Negroes. American Indians. Malays. In how many continents do you find Mongolians? Caucasians? What race chiefly occupies islands? Trace the northern limit of permanent inhabitants. Name the chief articles of human diet according to latitude. [See the meridian of 40° West from Greenwich, along which these are given.]

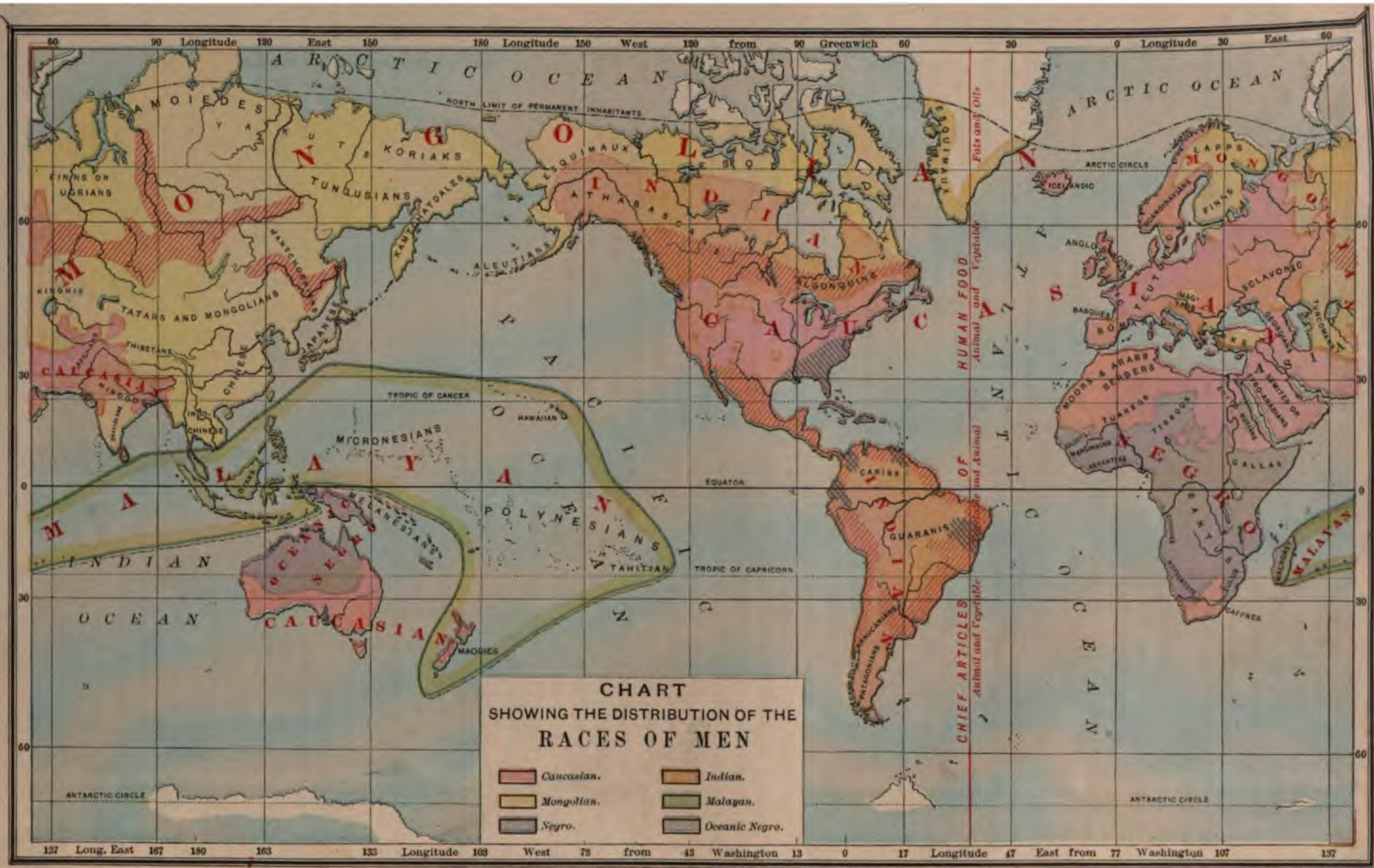

CHART
SHOWING THE DISTRIBUTION OF THE
RACES OF MEN

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are found which are best adapted to man's physical development.

An indigenous civilization has never had its birthplace under the blighting blasts of the Arctic regions, because there, from the cradle to the grave, life is one struggle for mere subsistence. The body is so pinched and starved by cold and hunger as to prevent the development of the mind.

Neither do the moist and overheated climates of the torrid zone appear to be favorable to mental development. There the rainy season and the constant heat dwarf and enervate the body. Cold may not pinch, nor hunger gnaw, yet fever racks the frame; and the mind, in its first and feeble steps toward civilization, is crippled by the ills of the body. Body and mind, moreover, lack in the torrid zone, by reason of its superabundant productiveness, the great stimulus to human exertion, necessity.

Man, to be civilized, must be beyond the reach of climatic extremes.

6. Man's Influence upon Physical Geography.—While, however, we notice the influence of physical geography upon man, we must also notice the influence of man upon physical geography. Although, like the brutes, he is strongly impressed by his material surroundings, he is unlike the brute creation in this: they cannot modify the conditions which surround them; he can. To him alone has been given authority, in the language of Genesis, "to subdue the earth." The methods to which he resorts are mainly three: (1) Drainage, (2) Irrigation, (3) Extension of the range of useful plants and animals.

In many cases skill and perseverance triumph over natural difficulties that seem insuperable.

DRAINAGE.—Immense changes are wrought by artificial drainage. Superfluous water, instead of being left to form marshes, saturate the soil, and be taken up by evaporation, is carried off underground through the drain-pipes; consequently, the air is not so largely impregnated with moisture as formerly, and the soil, instead of being constantly chilled by evaporation, is rendered warm, genial, and productive.

This result is particularly noticeable in England and Scotland, where very extensive areas have been drained and brought under cultivation.

Reclamation of Land.—Holland has been reclaimed from the sea. The water has been dyked out; and many parts of the country that were the bottom of the sea are now dry land, and though below the level of the sea, form the home of industrious and happy communities.

Years ago there were along the lower banks of the Mississippi, subject to overflow, and uninhabitable, "drowned lands," embracing an area larger in the aggregate than the State of New York. Many of these lands have been reclaimed by means of levees.

The "dyke" lands of Nova Scotia and New Brunswick have been reclaimed from the sweeping tides of the Bay of Fundy. They are probably the finest hay-lands in the world. Some of them have been cropped 200 years. They are as sure to yield as the fields of Egypt.

IRRIGATION.—By man's agency in using the waters of the Nile for irrigation, Egypt became in olden time the granary of the world. Canals conveyed the water to lands not reached by the flood. And to-day the Egyptian peasant is using with profit the devices employed by his ancestors more than 3,000 years ago. Much of the country yields three crops every year.

In India and Ceylon vast districts of country are rendered fertile by the use of tanks and reservoirs, which were constructed long ages ago for collecting the water in the rainy season, and distributing it in the dry, for the purposes of irrigation.

The dry regions of our own country also are now largely irrigated. In Utah, California, Arizona, New Mexico, and Colorado the wilderness has been, by this means, transformed into a garden. Some single "canals" with their distributing channels carry water to 150,000 acres.

RANGE OF PLANTS AND ANIMALS EXTENDED.—Races of men, species of animals, and families of plants have been carried from one country to another, and their geographical range enlarged.

Indian corn, tobacco, and the potato, with many other plants, the turkey and other animals, were indigenous to America. They have been carried to the Old World and acclimated. On the other hand the horse and cow, the sheep, hog, goat, ass, and other animals of the Old World, with wheat, oats, rye, barley, and rice, the sugar-cane and coffee, and a great variety of other plants, have been transported to America.

A few stray cattle and horses escaping to the pampas and llanos of South America, have multiplied exceedingly. So wonderfully have they increased that, upon the pampas, millions of them are slaughtered for their hides, horns, and tallow.

TOPICAL ANALYSIS.

III. MAN.

1. **Range of Human Habitation.**
    - Vertical range.
2. **Unity of Human Family.**
3. **Diversity.**
    - Causes.
4. **Division into Races.**
    - The Caucasian race. **Origin of [illegible]** Extent. **Characteristics. [illegible]**
    - The Mongolian race. **C[illegible]** gressive **character.**
    - The Negro **race.**

The Malay race. Extent. Characteristics.
American Indians. Extent. Important tribes. Characteristics. Former civilization.

5. Conditions favorable to Civilization.

Frigid and torrid climates, why unfavorable.

6. Man's Influence on Physical Geography.

Extent of influence. Drainage. Reclamation of land. Irrigation. Range of plants and animals extended.

Test Questions.—How is it that man has a wider range than any other animal? If we wished to divide the human family into three races only, how should the division be made? To what race do the Moors belong? The Siamese? The Hungarians? The Hottentots? The Fijians? The Sandwich Islanders? The Celts? The Slavs? The Tatars? The Bedouin? The Teutons? The Choctaws? The Aleutians? The Pawnees? Do you know of any important exceptions to the general non-progressiveness of the Mongolian race? Name some respects in which all the races except the Caucasians resemble each other.

IV. GEOGRAPHICAL DISTRIBUTION OF LABOR.

1. Distribution of Labor Dependent on Physical Geography.—Every nation has industries peculiar to itself. These, to a large extent, have their root in geographical circumstance, or in difference of climate.

To show how human labor, when unaffected by tariffs and untrammelled by legislation, would naturally distribute itself over the earth in obedience to geographical law, let us suppose two families to have been planted originally on the earth, one at the equator, the other in the Arctic regions. How different, on account of their geographical surroundings, would be their occupations!

The intertropical family would seek the shades of the groves, pluck the ripe fruit overhead, require little clothing, and be exempt from undergoing the hardships of toil to earn their daily bread. With little exertion on their part nature would supply their wants.

The Arctic family, on the contrary, would be clothed with skins and furs; the earth would produce no grain or vegetables for them. They would live by the chase and the bounties of the sea.

Diversified Industries in Middle Latitudes.—Now, suppose these two families gradually to extend themselves, the one toward the north, the other toward the south, meeting midway near the isotherm of 50°. [See map, pp. 72, 73.]

The occupations of both, as they continued to approach this middle ground, would no longer be directed, on one side mainly toward the sea, and

to the soil; but would be-

d.

family would

re occupations, some to the manufacture of clothing, others to the fabrication of implements for husbandry; others again to seafaring. Novel opportunities would present themselves to the northern community, and induce them likewise to subdivide their labor. They would divert a portion of it from the sea and the chase, and devote themselves to a greater or less extent to agriculture, to the forest, the mine, and the factory.

Such a diversity of occupation really exists among men. The middle latitudes, embracing regions lying not far from the isotherm of 50°, form a belt encircling the earth, where human occupations are most diversified. In some parts of this belt the tending of flocks and herds and the raising of stock are the chief industrial pursuits; in other parts agriculture, in others mining, manufacturing, seafaring and lumbering; in some, all of these occupations, or several of them, are combined.

As you go south of this middle ground, the attention of the people is devoted more and more to the field and the forest; and as you go north, more and more to hunting and the sea.

Turn your eye along this middle ground round the world, and you will find within it the most active seafaring and commercial peoples in the world, the greatest manufacturing nations, and the largest cities.

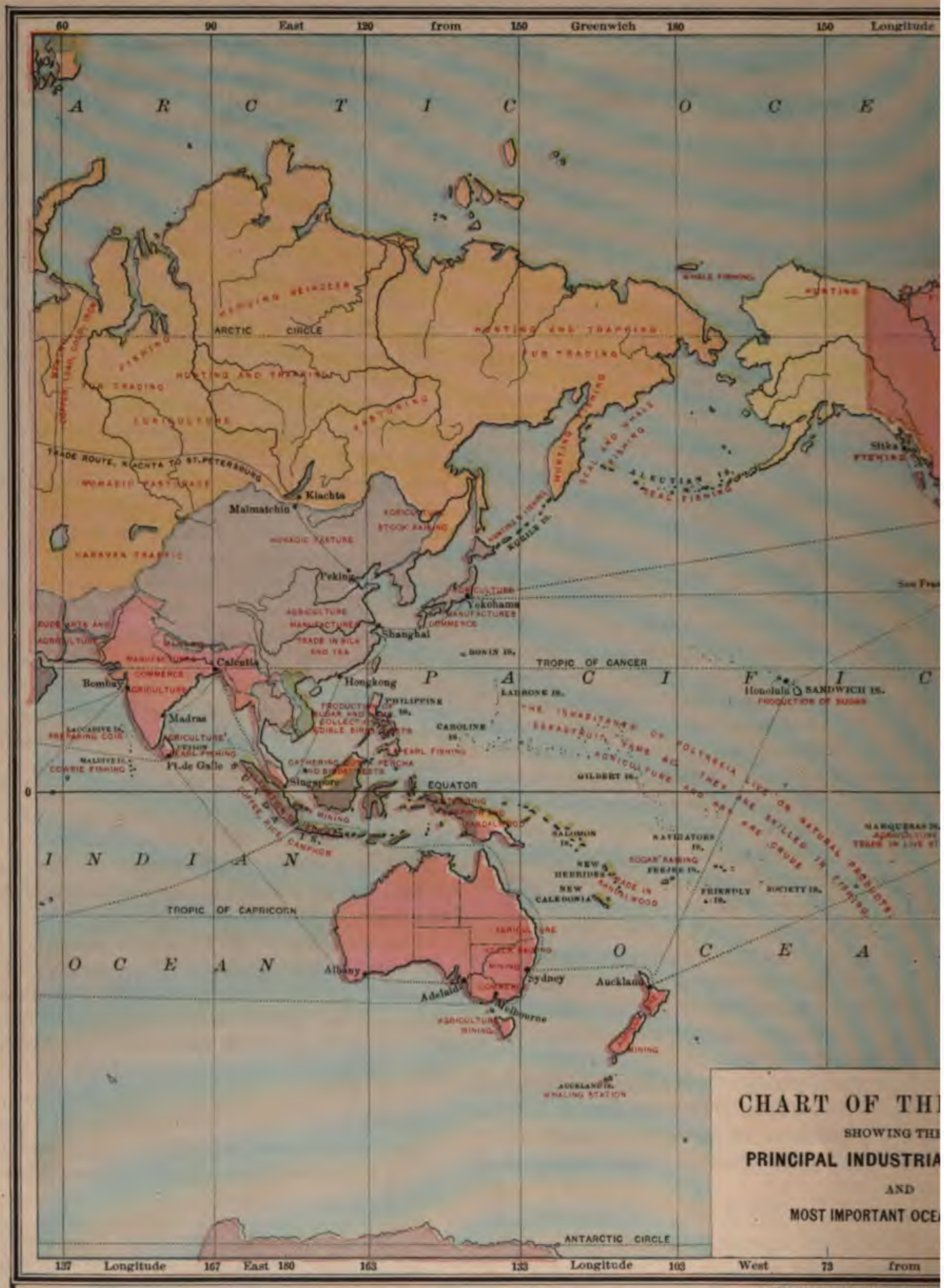
In America the United States for the most part is embraced within this belt. In Asia, Japan and parts of China, with their large cities, are included in it; while all the great commercial, manufacturing, mining and seafaring communities of Europe reside within it.

You can now perceive that there are geographical reasons why the people of South America, of Africa, India and of the tropical and sub-tropical regions of the earth should, in the main, be rather agricultural or mining in their industries than seafaring or manufacturing.

General Rule.—And in general it may be laid down as a rule; that *the industries of every country are connected with its geography, and that human labor is distributed, largely, in obedience to certain physical conditions.*

2. Industries of our own Country.—A brief survey of the industries of our own country will serve well to illustrate this law of the geographical distribution of labor.

Agricultural Pursuits.—Let us observe in the first place how the principle applies to our various agricultural pursuits. Climate, of course, furnishes the predominant reason why different products are raised in different parts of the country. But we shall notice that other minor causes are not without their influence.



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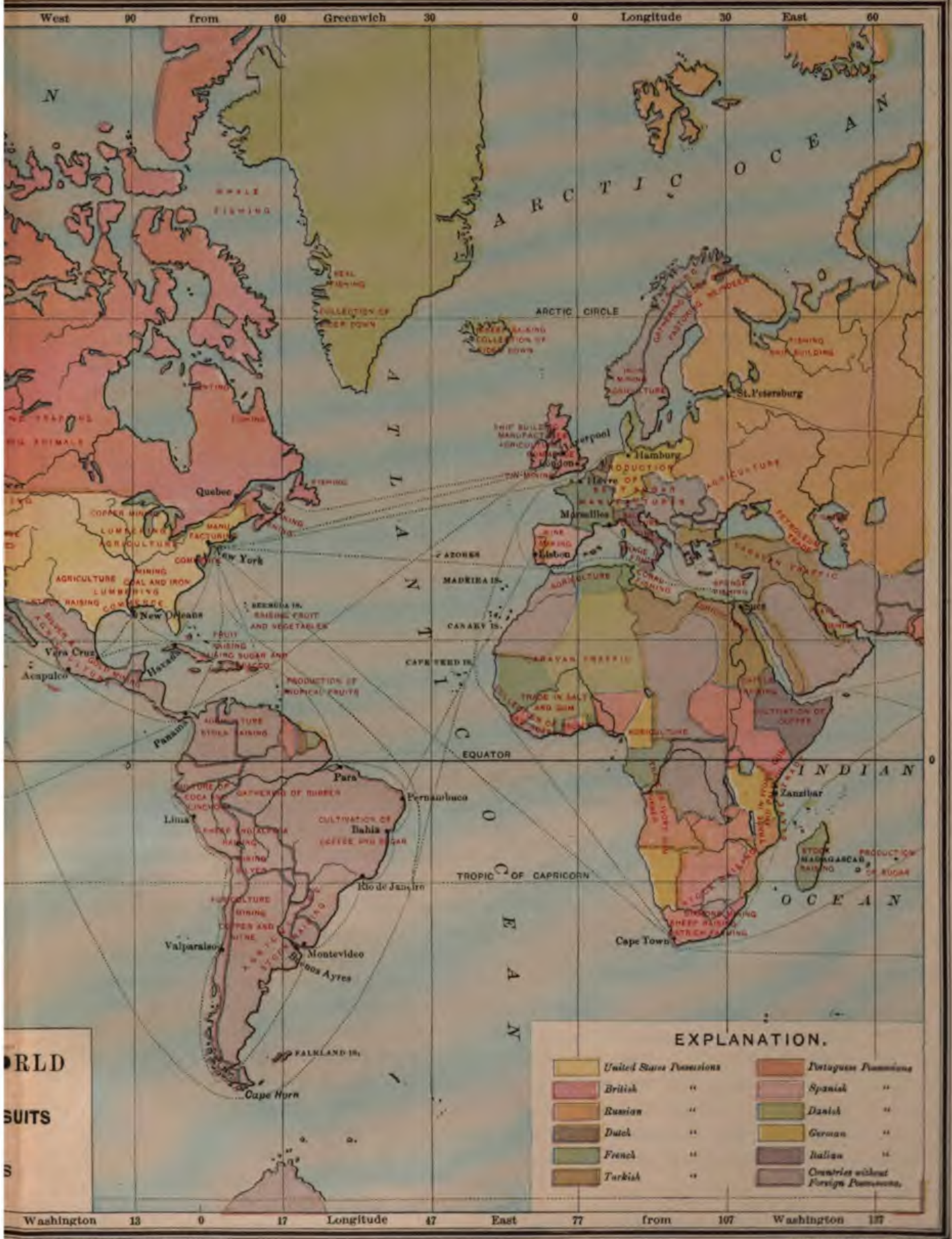
QUESTIONS ON INDUSTRIAL PURSUITS.

Name the leading occupations of Great Britain. Where is the making of beet-root sugar largely carried on? Silk culture? Wine? What is the great fruit-growing region of Europe? What are the occupations of northern Sweden and Norway? Of Russia? Spain? Of South Africa? Madagascar? Of the east and west coasts of Africa? Of Egypt? What is the great coffee-gro region of Africa?

Name some occupations of India. What impor metal is mined in the East Indian Archipelago? N sources of supply of camphor and sandalwood.

Mention some of the leading occupations of the board of Canada. Of different sections States. Central America and the West ico. Brazil. Peru. Chile. The



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What are the employments of Greenland? Of Polynesia? New Caledonia? New Zealand? Tasmania? Australia? Sumatra? Java?

Mention regions in which hunting and trapping fur-bearing animals is a leading occupation. What great traffic in Asia is carried on by means of caravans?

Name occupations of China and Japan. Mention any [illegible] mes imply that they were [illegible] na or Japan.-

Name regions where sperm and right whale-fishing is carried on. Coral and pearl fishing.

Trace routes from San Francisco to Japan. Hongkong. Sydney. New Zealand.

Trace the routes from the Indian Ocean to New York. From Bombay to Liverpool via the Suez Canal. Two routes from Liverpool to Australia. From New York to Australia via Isthmus of Panama. What would be the effect of cutting a Panama Canal?

The Mississippi Valley.—In the Valley of the Mississippi, which may be regarded as the great agricultural region, we find, as we advance northward from Louisiana, a succession of climatic belts, and a corresponding variety of crops engaging the attention of the husbandman.

First of all, near the borders of the Gulf of Mexico, comes a belt in which sugar and rice are important crops. Leaving this belt, we enter regions, one after another, specially adapted to the cultivation of cotton, tobacco, corn and wheat, hemp, the grape, and orchard fruits.

The Atlantic Slope.—If the journey lie along the Atlantic Slope from Florida to Maine, we find a similar succession of belts and products; but with this striking difference, owing to the influence of the sea, viz., that the climates are milder and the belts broader.

In the "Tide-water Country" these belts are so widened that rice cultivation is carried up into North Carolina, cotton is raised in Virginia, and figs in Maryland—all much farther north than on the west of the Alleghanies.

In the tide-water country of Georgia and the Carolinas, rice is a more important article of cultivation than in Alabama, Mississippi and Texas. There is a geographical reason for this. The Atlantic has tides, the Gulf of Mexico almost none. Rice-fields require, in certain stages of the crop, to be flooded. The tidal creeks and rivers of the seaboard afford facilities for this which are lacking in the tideless streams of the Gulf States.

At the same time Louisiana has become the first rice-growing State in the Union. There are reasons for this. In the Mississippi delta the river is high above the cultivated ground. Consequently a supply of water can be obtained by simply tapping the river. In the southwestern "parishes," away from the river, immense areas of low and level lands are readily irrigated from artificial reservoirs.

The Pacific Slope.—The agricultural pursuits of the Pacific slope, owing to its physical peculiarities, differ from those of the Atlantic. No rice or cotton is cultivated. But the region is unsurpassed for its wheat and fruit crops; the olive, vine and orange yield abundantly, while stock-raising and wool-growing are profitable employments.

Other Industrial Pursuits.—Considering now the various other industrial pursuits of our people, we find it to be the rule that Physical Geography has largely determined how the occupants of each section shall employ themselves.

Here we view far-reaching grass-covered plains which naturally suggest the occupations of stock-raising, dairying, or wool-growing. Elsewhere we traverse forests famed for lumber, ship-timber val stores. In yet another region we observe that attention is directed to the great lakes or water-courses for fish and fowl; or to the interior of the earth for minerals; or to commerce, manufacturing and navigation.

All these occupations are, it is true, adopted according to individual fancy, yet still they are clearly prompted and controlled by geographical circumstances.

Industries of New England and Gulf States Contrasted.—A very striking illustration of the law of geographical distribution of labor is obtained when we contrast the leading occupations of such widely separated sections of our country as the Gulf States and New England.

In the former there is no "wintry weather." The husbandman may labor in the field all the year long, and the soil yields abundantly.

In New England, on the other hand, the ground is covered with snow, or is frozen hard, during four or five months in the year. How is New England industry to ply its hand during this period? It cannot till; and it will not do to stand idle.

Forests upon the mountains, ships upon the sea, quarries of valuable stone, and above all factories of every description furnish ample employment for the industrious population. New England is a manufacturing bee-hive. Its polished granites and marbles are distributed everywhere along the Atlantic seaboard for building and ornamental purposes; its manufactures find a market in every part of our own country and are exported to the far distant seaports of China and Japan and the islands of the coral seas.

Louisiana, and her sister Southern States, on the other hand, want laborers for their harvests of cotton, corn, sugar, rice, naval stores, hemp, tobacco, etc. There are, therefore, inducements peculiar to each of these two sections which allure the people of one to this branch of industry, the people of the other to that, according to geographical circumstances. In one, these inducements lead to the sea and the factory; in the other they point to the bosom of the earth.

Mining and Manufacturing.—If coal and the useful metals are found in any region, manufacturing interests will sooner or later be developed. It is in no small degree owing to her vast deposits of coal and iron that Great Britain occupies her extraordinary position as a manufacturing nation. Pennsylvania, Ohio, Alabama, Illinois, Virginia, Maryland, Michigan, and other States similarly rich in the useful minerals, are actively engaged in mining and metallurgy.

FISHING AND COMMERCE.—Again, people are maritime in their habits from physical reasons; partly because they are adjacent to the sea; and partly because, owing to the conditions which surround them, the bounties of the sea are to them more enticing than the bounties of the land. Hence you find that the seafaring populations of the world belong chiefly to those countries where, either from the poverty of the soil, the severity of the climate, or the high price of food, it is easier for some of the population to make a living by braving the sea than by delving on shore.

You do not find ships at sea manned by sailors from the Mississippi Valley and the seacoast of the Southern States, where lands are cheap, climates mild, and where the soil is lavishly kind; but rather from New England, Great Britain, and the countries of Northwestern Europe, where, largely on account of geographical circumstances, the laboring man finds it in many cases easier to make a living at sea than on shore.

Origin of Commerce.—It only remains to point out how commerce between nations originates naturally in the facts of physical geography. Articles required for food and shelter, comfort or luxury, being irregularly distributed over the globe, it becomes necessary that human industry should be partly directed to the exchanging of the natural and artificial products of one region for those of another. As will be seen by an inspection of map on pages 122 and 123, the routes of commerce are determined in all cases by the irregular distribution of valuable products.

3. Conclusion.

3. Conclusion.—Let us now briefly sum up the conclusions of our science. Physical Geography teaches us to see order and law, harmony and design in every part of the terrestrial machinery.

We learn from it that the very position of the earth at a certain distance from the sun has a purpose—that the inclination of its axis has an important bearing upon climate and seasons; that not without reason do the mighty waters occupy so large a proportion of its surface; that they yield of their abundance to refresh the dry and thirsty land; that the wayward winds are obedient to law, and blow for definite reasons; nay, that even the storm and hurricane reveal to us their ordinances, although we may not discern their purposes.

We learn that mountains are not simply features of the landscape intended to impress us with their grandeur and beauty, but that they control the rainfall and determine where the vapor-laden winds shall discharge their burden of refreshment; and, stranger than this, Physical Geography instructs us to regard the very deserts, with their arid and burning sands, not as waste areas, but rather as invaluable parts of the vast mechanism by which the lands of the earth are clothed with verdure, and the labors of the husbandman crowned with success.

Borrowing from the sister sciences of chemistry, botany, and zoology, Physical Geography discloses to us how wondrously the inorganic world is adapted to the support of plant and animal life, and how marvellously these interact the one upon the other. It tells us that the sturdy oak absorbs its strength from the unseen air, while the lichen and the daisy spend their lives in elaborating an atmosphere that may support the life and energy of man and beast.

In a word, the science of Physical Geography unfolds to us this grand view of our planet, that in all its arrangements there is proof of All-wise and beneficent design. The study leads to a deeper understanding of the Psalmist's words, "The earth is full of the goodness of the Lord; so is the great and wide sea also."

TOPICAL ANALYSIS.

IV. GEOGRAPHICAL DISTRIBUTION OF LABOR.

1. Distribution Dependent on Physical Geography.

An illustrative example. Diversified industries in middle latitudes. Gradual increase in diversity as middle latitudes are approached. Important industrial pursuits in those regions. Consequent prosperity. Characteristic industries of polar and equatorial regions. General rule.

2. Industries of our own Country.

Agricultural pursuits. The Mississippi Valley. Successive climatic belts and their characteristic products. The Atlantic Slope. Cause of its broader belts. Advantages for rice cultivation. The Pacific Slope, agricultural pursuits of. Influence of physical circumstances on other industries of the country.

Industries of New England and Gulf States contrasted. Mining and manufacturing promoted by mineral wealth. Circumstances tending to develop the industries of fishing and commerce. Origin of commerce.

3. Conclusion.

Evidences of harmony and beneficent design in the terrestrial machinery.

TEST QUESTIONS.—Name three or four causes, aside from climate, which may affect the industries of a people. Name some advantages of diversified industries. Do you think there is any intellectual advantage, and why? Difference between savage and civilized nations as to diversity of industries. Is the diversity likely to increase? Why? How does increasing diversity affect commerce? In the United States there are more railroads running east and west than north and south: can you give any reasons for it?

TOPICAL ANALYSIS FOR REVIEW.

- **Relations Between Plants and Animals.**
  - Life.
    - Organic and inorganic nature.
    - Flora and Fauna. Points relating to them to be considered.
  - Mutual Dependence of Plants and Animals.
    - What animals require for respiration.
    - Effect of the change of oxygen.
    - Deleterious product, how disposed of.
    - Oxygen prepared by plants.
    - Food of animals supplied by plants.
    - Mutual checks.
    - Influence of the winds.

- **Range of Plants and Animals.**
  - General facts.
    - Range dependent on climate.
    - Modifications by climate. Illustrations.
  - Zones of Vegetation.
    - How defined.
    - Horizontal zones. Limits and characteristic plants of each.
    - Vertical Zones. Correspondence to horizontal.
  - Range of Food Plants.
    - The cereals.
    - The potato, banana and mandioca.
    - Bread-fruit and sugar cane.
  - Beverage Plants.
  - Spices and Narcotics.
  - Plants used for Clothing.
  - Medicinal Plants.
  - Useful Trees.
  - Flora of the Sea. Algæ.
  - Distribution of Animals.
    - Why dependent on climate.
    - Zones of animal life.
    - Zoological regions.
      - Important and peculiar forms in each.
      - Australian and S. American regions, for what remarkable.
  - Range of Draught Animals. Special adaptation of some to locality.
  - Limited Range of some Animals.
  - Fauna of the Sea.
    - Range, by what mainly determined.
    - Life of tropical waters. Of cool waters.
    - Range of the seal; reef-building polyp.
  - Floral Regions.
    - Reasons for coincidence with zoological regions.
    - Plants peculiar to each.

- **Man.**
  - Range of Human Habitation. Vertical range.
  - Unity of Human Family. Diversity. Causes of diversity.
  - Division into Races.
    - Caucasian race.
      - Divisions. Extent.
      - Characteristics. Superiority.
    - Mongolian race.
    - Negro race.
    - Malay race.
    - American Indians.
      - (Mongolian, Negro, Malay, American Indians:) Extent. Characteristics.
  - Conditions Favorable to Civilization. Frigid and Torrid Climates, why unfavorable.
  - Man's Influence on Physical Geography.
    - Extent of influence.
    - Ways in which it has been exercised.

- **Geographical Distribution of Labor.**
  - Dependent on Physical Geography. Diversified industries in middle latitudes.
  - Industries of our own country.
    - Agriculture.
      - The Mississippi Valley.
      - The Atlantic Slope.
      - The Pacific Slope.
    - Influence of circumstances on other industries.
    - Industries of New England and Gulf States contrasted.
    - Mining and manufacturing.
    - Fishing. Commerce. Origin of.
  - Conclusion. Evidences of harmony and design.

PRONOUNCING VOCABULARY.

Explanation.—In this Vocabulary the best and most recent authorities have been consulted for both spelling and pronunciation. ā *or* ay, ē, ī, ō, ū, are to be pronounced as in bate, mete, bite, note, tube; ă, ĕ, ĭ, ŏ, ŭ, as in bat, bet, bit, not, but. The sound of *a* in *far* is indicated by *ah*; *a* in *fall*, by *aw*; *o* in *do*, by *oo*; *g* in *get*, by *gh*. U represents the sound of eu in French, which resembles the sound of e in her.

The nasal sound occurring in some French words is indicated by N, as Toulon (too-loN); this nasal sound is somewhat like that of *ng* sounded through the nose. Letters inclosed by ( ) indicate pronunciation. In some cases two accents will be found in one word. The principal accent is represented by ′, the secondary by ‵.

Abyssinia (ab-is-sin'i-a).
Aconcagua (ah-kon-kah'gwah).
Aegean (ē-jē'an).
Afghanistan (af-ghan-is-tahn').
Alas'ka.
Aleutian (al-oo'she-an).
Altai (ahl-tī').
Am'a-zon.
Amboyna (am-boi'nah).
An'des (an'dēz).
Antigua (an-tē'gwah).
A-pa'che.
Ap-pa-la'chi-an.
Ap'en-nīnes.
Ar'ab.
Ar'a-rat.
A-rau-cā'ni-an.
Archipelago (ark-ī-pel'a-go).
Argentine (ar'jen-tēn).
Ari-zo'na.
Artois (ahr-twah').
Az'ov (az'of).
Az-ores'.

Baikal (bī'kahl).
Balkan (bahl-kahn', *or* bal'-kahn).
Baltic (bawl'tic).
Bar-bā'does (-dōz).
Bedouin (bed'oo-ēn).
Bering (bē'ring).
Bel-oo-chis-tan'.
Bencoolen (ben-koo'len).
Bengal (ben-gawl').
Bep'ho.
Ber-nard'.
Bhooj (booj).
Blanco (blang'ko).
Bogota (bo-go-tah').
Bo-liv'i-a.
Bor'ne-o.
Boschen (bo-shen).
Brah-ma-poo'tra.
Brazil (brah-zil').
Bund (boond).
Bur'mah.

Cairo (kī'ro; in U. S. kā'ro).
Callao (kal-lah'ō, *or* kal-yah'ō).
Campagna (cam-pan'yah).
Can'a-da.
Cañon (can'yon).
Caracas (cah-rah'cas).
Car-ib-be'an.
Cassiquiare (cah-se-kē-ah'rā).
Cau'ca-sus.
Celebes (sel'e-bez).
Ceylon (sē'lon, *or* se-lon').
Charybdis (ka-rib'dis).
Cherrapungee (cher-ah-poon-je').
Chili (chil'le).
Cinchona (sin-ko'nah).
Cir-căs'sian.
Co'mo.
Comorin (kom'o-rin).
Coseguina (ko-sā-ghē'nah).
Cotopaxi (co-to-pax'e).
Cumana (ku-mah-nah').

Dec'can.
Dnieper (nē'per).
Dniester (nēs'ter).
Dwina (dwē'nah).

Ecuador (ek-wa-dōr').
Esquimaux (es'ke-mo).
Estacado (es-tah-kah'do).
Etesian (e-tē'zhan).
Eu-phra'tes (yoo-frā'tēs).

Fiord (fe-ord').

Gal-a-pa'gos (gal-a-pah'gōs).
Ganges (gan'jēz).
Garonne (gah-ron').
Géant (zhā'oNg).
Ge-nē'va.
Geysers (ghī'zers).
Ghauts (gawts).
Gobi (gō'bē).
Grenelle (greh-nell').
Grim'sel.
Guadaloupe (gwah'da-loop).
Guatemala (gwah-te-mah'la).
Guayaquil (gwī-ah-kēl').
Guiana (ghē-ahn'a).
Guinea (ghin'e).

Ham'mer-fest.
Han'lē.
Hawaii (hah-wah'e).
Hayti (hā'te).
Her-cu-lā'ne-um.
Himalaya (him-ah'la-ya *or* him-a-lā'ya).
Hoogly (hoog'lee).

Ibi Gamin (ee'be gah'min).
Illimani (ēl-ye-mah'ne).
Indies (in'diz).

Jamaica (ja-mā'kah).
Jan Mayen (yahn-mī'en).
Java (jah'vah).
Jax-ar'tes (tez).
Jorullo (ho-rool'yo).

Kamtchatka (kam-chat'ka).
Kar-a-kō'rum.
Keni'a (ē'a).
Ke'o-kuk.
Kerguelen (kerg'e-len).
Khamsin'(seen).
Khar-toom'.
Khasia (kas'se-ah).
Khingan (kin-gan').
Khiva (kē'vah).
Kilauea (kee-lōw'ā'ah).
Kilima-Njaro (kil-e-mahn-jar-o').
Kirghiz (kir-ghēz').
Kliutchev.
Kuen Lun (kwen loon).
Kurile (koo-rēl, *or* koo'ril).
Ku'ro Si'wo (sē'wo).

Lab-ra-dōr'.
La'-do-ga.
La Plata (lah plah'tah).
Lar'sa.
Lauricocha (low-re-co'chah).
Le'chaud (lā-sho').
Lipari (lip'a-re).
Llano Estacado (lyah'no es-tah-kah'do).

Llanos (lyah'nōs).
Lo-fō'den.

Macassar (ma-kas'sar).
Mad-a-gas'car.
Magellan (ma-jel'lan, *or* maj-el-lan').
Maggiore (mahd-jo'rā).
Malacca (ma-lak'ka).
Ma-lay'.
Maravaca (mah-rah-vah'kah).
Marquesas (mar-kā'zas).
Mar-a-cay'bo (-kī-bo).
Martinique (mar-te-nēk').
Mauritius (maw-rish'e-ūs).
Maz‵at-lan'.
Mekong (mā-kong').
Medusæ (me-du'sā).
Mer de Glace (mair de glass).
Messina (mes-sē'nah).
Mil-le-po-ra.
Mon'derf.
Mon-gō'li-an.
Mont Blanc (mŏN blŏN').
Mozambique (mo-zam-bēk').

Nevada (ne-vah'dah).
New-found'land (*or* nu'fund-land).
New Zea'land.
Nī-ag'a-ra.
Ni'ger (nī'jer).
Nisyros (nis'e-ros).
Nyanza (ne-an'zah).
Nyassa (ne-as'sah).

O-des'sa.
Okhotsk (o-kotsk').
Onē'ga.
Oppido (op'pe-do).
Orizaba (o-re-zah'bah).
O-ri-no'co.
Ox'us.

Pamir (pah-mēr').
Pamperos (pam-pā'ros).
Pan-a-ma' (-mah).
Pa-pan-da-yang'.
Parime (pah-rē'mā).
Pas'to.
Pa-ta-go'ni-a.
Pe-king'.
Peling'.
Periades (pay-re-ad).
Peru (pe-roo').
Plata (plah'tah).
Plateau (pla-to').
Polynesia (pol‵e-nee'she-a).
Pompeii (pom-pā'yē).
Porto Rico (port'o rē'ko).
Puna (poo-nah').
Puy de Dome (pwee-deh-dōm').
Pyr'-e-nees.

Quito (kē'to).

Rainier (rā'neer).
Rē'gia.
Rhine (rīn).
Rhone (rōn).
Riobamba (re-o-bam'bah).
Rio de la Plata (rē'o dā lah plah'-tah).
Roque (rōk).

Sahara (sah-hah'rah).
Salzwerk (zalts'verk).
Santorini (san-to-ree'nee).
St. Etienne (sant ā-te-ĕn').
St. Gothard (go-tar').
Sas-katch'e-wan.
Sen-e-gam'bia (be-a).
Sierra Madre (se-er'rah mah'drā).
Sierra Nevada (se-er'rah ne-vah'-dah).
Simplon (sam-ploNg).
Sioux (soo).
Si-roc'co.
Skaptar Jōkul (skap'tar yn-kool').
Sol-fa-ta'ra (tah'rah).
Spitz-berg'en.
Stanovoi (stahn-no-voi').
Steppes (steps).
Strom'bo-li.
Suleiman (soo-lā-mahn').
Sumbawa (soom-baw'wah).
Sumatra (soo-mah'tra).
Sun'da.
Sy'ri-a.

Tahiti (tah-hē'te).
Tal-efre (tal-āfr).
Tanganyika (tahn-gahn-yē'kah).
Tanjier (tahn-jēr').
Thian Shan (te-ahn'shahn).
Thibet (tib'et *or* tib-et').
Tī'gris.
Titicaca (tī-tī-kah'kah).
To'kio (ke-o).
Torricelli (tor-re-chĕl'le).
Tor-to'la.
Tristan d'Acunha (tris-tan da-koon'yah).
Tsetse (zeet-zee).
Tsi-en-tsang'.
Tunguragua (toong-goo-rah'gwah).
Ty-phoon'.

Upernavik (oo'per-nah'vik).
U'ral *or* Ou'ral.
U'ra-nus.
Urumtsi (oo-roomt'see).

Valdai (val'dī).
Venezuela (ven-e-zwē'la).
Vindhya (vind'yah).

Wen'er.
Werchojansk (ver'ko-yansk).

Yablonoi (yah-blo-noi').
Yakutsk (yah-kootsk').
Yang-tse-Kiang (yahng‵tse ke ang').
Yo-sem'i-te.
Yu'kon.

Za'gros (zah'gros).
Zambezi (zam-bā'ze).

TABLES OF MEAN TEMPERATURE AND RAINFALL.

NAMES OF PLACES.	North Lat.	Jan'y. (Below zero—)	July.	Year.	Annu'l rainfall in inches.
UNITED STATES.					
Albany, N. Y.	42°39'	24.3	72.1	48.2	40.56
Amherst, Mass.	42 22	23.7	71	46.7	43.96
Astoria, Or.	46 11	43	61.6	52.2	77.12
Augusta, Ga	33 28	46.7	81.9	64	46.78
Austin, Texas	30 16	46.4	80.7	66.7	33.52
Baltimore, Md	39 17	30.9	75.2	53.1	41.29
Baton Rouge, La	30 26	53.5	81.8	68.1	60.53
Boston, Mass.	42 22	27.8	71.6	48.9	40.61
Brownsville, Tex.	25 53	60.4	84.2	73.7	28.63
Buffalo, N. Y.	42 53	25.4	70.2	46.1	37.37
Cedar Keys, Fla.	29 7	55.6	81.3	70.5	45.78
Cincinnati, O	39 6	30	74.5	53.8	42.96
Chapel Hill, N. C.	35 54	41.5	78.2	59.7	42.71
Charleston, S. C.	32 46	48.1	80.1	65.9	44.82
Chicago, Ill	41 53	23.6	70.8	49	35.62
Cleveland, O.	41 30	27.3	72	48.9	37.70
Columbia, S. C.	33 57			57.1	50.83
Concord, N. H.	43 12	21.2	67.1	44.5	40.32
Denver, Col.	39 44	32	73	48	14 57
Des Moines, Iowa	41 35	27.4	76.5	49.7	31.64
Detroit, Mich.	42 20	27	69.7	47.2	32.84
Dubuque, Iowa	42 30	19.8	75.2	49.4	33.66
Eastport, Me.	44 54	22.4	62.3	43	47.11
Fort Benton, Mont	47 50	16.5	73.6	48.2	13.27
Leavenworth, Kan.	39 21	28	76.7	52.8	39.46
Fortress Monroe, Va.	37 2	36.5	78.2	59.9	41.58
Ft. Snelling, St. Paul, Minn	44 53	13.7	73.4	44.6	26.23
Fort Yuma, Cal	32 44	56.4	92.3	73.6	3.96
Galveston, Tex.	29 18	48.1	83	69.4	51.5
Huntsville, Ala.	34 43	42	76.4	59.1	55.35
Key West, Fla	24 34	69.5	82.5	76.4	39.01
Little Rock, Ark	34 42	40	80	62.3	
Los Angeles, Cal.	34 3	52.8	73	62	14.64
Louisville, Ky.	38 3	33.8	74.6	54.9	48.12
Memphis, Tenn	35 8	41.7	79.9	60.8	44.57
Milwaukee, Wis.	43 3	25.2	69.8	46.4	34.23
Mobile, Ala	30 41	57.6	83.7	70.3	62.88
Nantucket, Mass.	41 17	34.9	71	50.4	41.18
Nashville, Tenn	36 9	38.2	79.5	58.5	50.68
Natchez, Miss.	31 34	52.3	81.3	67.1	54.39
New Haven, Conn.	41 18			50.8	45.44
New Orleans, La.	29 57	55.3	82.9	69.06	55.17
New York, N. Y.	40 42	30.2	74 8	51.92	46.52
Pembina, Dak.	49 50		74.4		20.70
Pensacola, Fla.	30 24	53.6	82.3	68.7	
Philadelphia, Pa.	39 57	32 1	74.7	52.7	43.29
Point Barrow, Alaska	71 21	-18.5	36.1	7.1	
Portland, Me.	43 39	22.8	68.2	45.2	37.88
Portland, Or.				53.23	47 20
Providence, R. I	41 50	27.5	70.6	47.9	43.33
Richmond, Va.	37 32	33.7	77 6	56.2	38.51
Rochester, N. Y.	43 8	26.9	69.9	47	33.63
Sacramento, Cal	38 34	45.3	73.9	59.9	19.34
St. Louis, Mo	38 37	31.4	78.2	55	40.69
Salt Lake City, Utah.	40 46	27.1	81.5	51.2	24.31
San Diego, Cal.	32 42	51 9	72.7	62	9.31
San Francisco, Cal	37 48	49 6	57.9	55.23	21.49
Santa Fé, N. M	35 41	31.4	72.6	50.6	14.91
Savannah, Ga	32 5	54.4	81.4	67.4	48.67
Sitka, Alaska	57 3	32	55.5	42.36	84.90
Washington, D. C.	38 53	33.3	76.7	53.56	38.95
West Point, N. Y	41 24	28.3	73.7	50.7	46.82
NORTH AMERICA.					
Assiniboine, Manitoba	50	-2 9	66.6	35 3	
[illegible]				[illegible]	[illegible]
Guatemala, Cent. Am.	14 40	65	68 9	67 8	55
Halifax				43.64	53.35
Havana, Cuba	23 9	71 4	81.4	79 6	46.25
Matamoros, Mexico	25 52	[illegible]	[illegible]	[illegible]	[illegible]
Mexico, Mexico	19 25	[illegible]	[illegible]	[illegible]	24.65
Montreal, Canada	45 31	[illegible]	73 2	[illegible]	[illegible]
Quebec				[illegible]	[illegible]
St. Johns, Newfoundland	47 35	23.4	56	[illegible]	[illegible]
St. Thomas, West Indies	[illegible]	[illegible]	[illegible]	[illegible]	35
Upernavik, Greenland	72 40	-12.3	[illegible]	[illegible]	[illegible]
SOUTH AMERICA.					
Bogota, U. S. of Colombia	4 36	57	58 2	[illegible]	[illegible]
Cumana				[illegible]	[illegible]
Lima, Peru (south lat.)	12 3	[illegible]	[illegible]	73.3	[illegible]
Quito, Ecuador (south lat.)	0 14	[illegible]	[illegible]	[illegible]	
Rio Janeiro, Brazil (south lat.)	22 54	79.6		[illegible]	[illegible]
Valparaiso, Chili (south lat.)	33 2	66	57.3	[illegible]	[illegible]
Buenos Ayres				[illegible]	34.[illegible]
Para				[illegible]	

NAMES OF PLACES.	North Lat.	Jan'y. (Below zero—)	July.	Year.	Annu'l rainfall in inches.
EUROPE.					
Archangel, Russia	64 33	22.5	52.2	35.5	15.61
Astrakan, Russia	46 21	19.9	77.9	49.2	6.12
Athens, Greece	37 58	45.5	79.5	62.4	10
Belgrade, Turkey	44 50	33.3	76.6	54.2	26
Bergen, Norway	60 24	35	60.4	46.8	87.61
Berlin, Germany	52 45	28.1	66.2	48.74	20.54
Bordeaux, France	44 51	42.4	69.1	55.1	34.25
Bremen, Germany	53 5	29.6	64.6	48.1	24
Brussels, Belgium	50 51	36	64.8	50.3	28.77
Christiania, Norway	59 55	21.31	61	41.1	21
Constantinople, Turkey	41 0	40.4	74.1	57.6	29
Dublin, Ireland	52 23	40.4	58.2	48.4	28.28
Edinburgh, Scotland	55 58	37.4	58.5	47.1	19
Ekaterinburg, Russia	56 50	2.3	63.8	33.2	13.99
Florence, Italy	43 47	40.8	76.3	57	35
Hammerfest, Norway	70 40	22.5	53.2	35.42	14.12
Lisbon, Portugal	38 43	48.6	69.8	59.5	27
London, England	50 30	37.4	64.1	51.44	27.14
Lyons, France	45 45	36.3	70.6	52.4	30.55
Madrid, Spain	40 25	44.7	76.3	57.56	14.96
Milan, Italy	45 28	33.8	74.5	54.6	38
Moscow, Russia	55 45	11.9	67.8	40.4	21.11
Naples, Italy	40 51	46.8	75.4	59.9	29.64
Odessa, Russia	46 25	26.1	71.5	49.2	15.83
Paris, France	48 50	35.4	65.6	51.46	20.16
Reykjavik, Iceland	64 8	30	56.2	37.94	30.25
Rome				59.54	31.49
St. Petersburg, Russia	59 57	15.5	62.5	38.46	18.50
Vienna, Austria	48 12	28.9	69.5	50.72	23.42
ASIA.					
Aden, Arabia	12 46	72.6	83.4	80.2	
Amboyna, Molucca Ids.	3 46	80.5	77	79.1	140.78
Bagdad, Asiatic Turkey	33 20	48.6	93.2	73.6	6
Bankok, Siam	13 38	76.7	82	81.1	
Barnaul, Siberia	53 20	-4.4	67.5	32.3	10.11
Batavia	6 9	77.7	78	78.8	74.35
Bombay, Ind.	18 56	73.3	80.7	79.6	74.45
Calcutta, India	22 33	71.7	84.2	77.80	62.90
Canton, China	23 6	52.5	83	69.9	69.30
Cherrapunjee					500.00
Irkutsk, Siberia	52 17	-6.5	64.9	31.82	16.45
Jerusalem, Syria	31 47	46.7	76.4	63.6	
Manila, Philippine Ids	14 36	77.1		81.50	65.52
Nagasaki, Japan	32 45	42.3	79.3	61	72.90
Nikolaewsk				27.30	16.27
Ochotsk				22.82	7.32
Peking, China	39 54	25.8	79.9	53.30	24.32
Petropaulovski, Kamtchatka	53	20.3	58.1	36.14	48.36
Singapore	1 17	78.4	82.2	81.29	92.74
Tiflis	41 41	32.4	73.6	55	19.30
Tobolsk, Siberia	58 12	-2.9	63.4	31.82	18.62
Tomsk				30.56	15.67
Werchojansk				1.94	
Yakutsk, Siberia	62	-41.3	68.2	12.4	13.71
AFRICA.					
Algiers, Algeria	36 47	59.1	80.4	62.96	31.10
Cairo, Egypt	30 2	56.3	85.6	71.3	0
Cape Town, Cape Colony (s. lat.)	33 56	67.6	54.4	64.37	16.98
Christiansborg, Guinea	5 24	81.1	77.1	80.4	144
Funchal, Madeira	32 38	62.5	72.5	65.6	30.57
ISLANDS OF THE PACIFIC.					
Adelaide, Australia (s. lat.)	34 55	[illegible]	54.2	[illegible]	22
Auckland, New Zealand (s. lat.)	36 50	[illegible]	[illegible]	58.6	[illegible]
Honolulu, Sandwich Ids.	21 18	71.7	78.9	75.4	22
Melbourne				57.4	[illegible]
Sydney, Australia (s. lat.)	33 52	71.7	49.5	62.3	[illegible]

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